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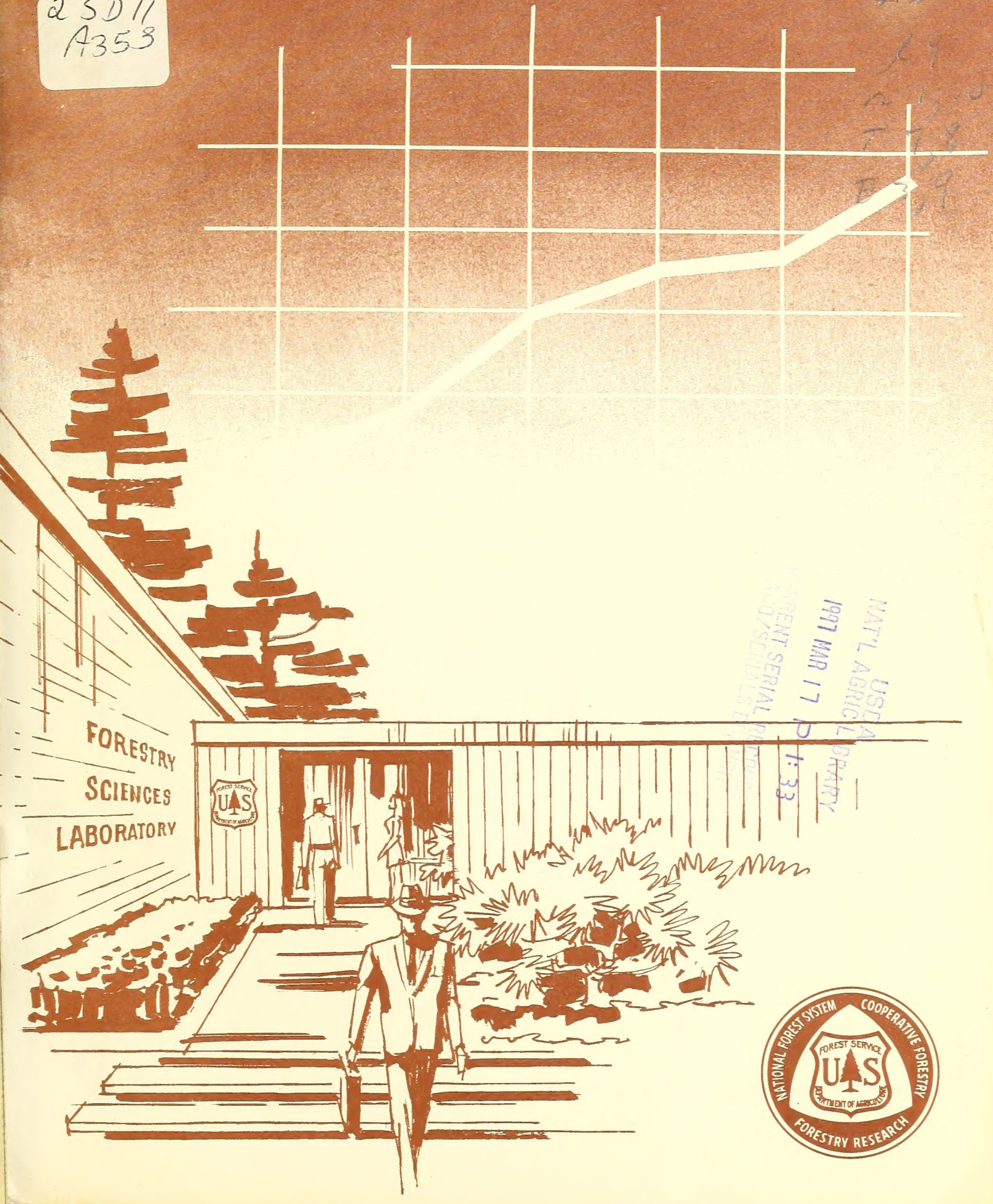

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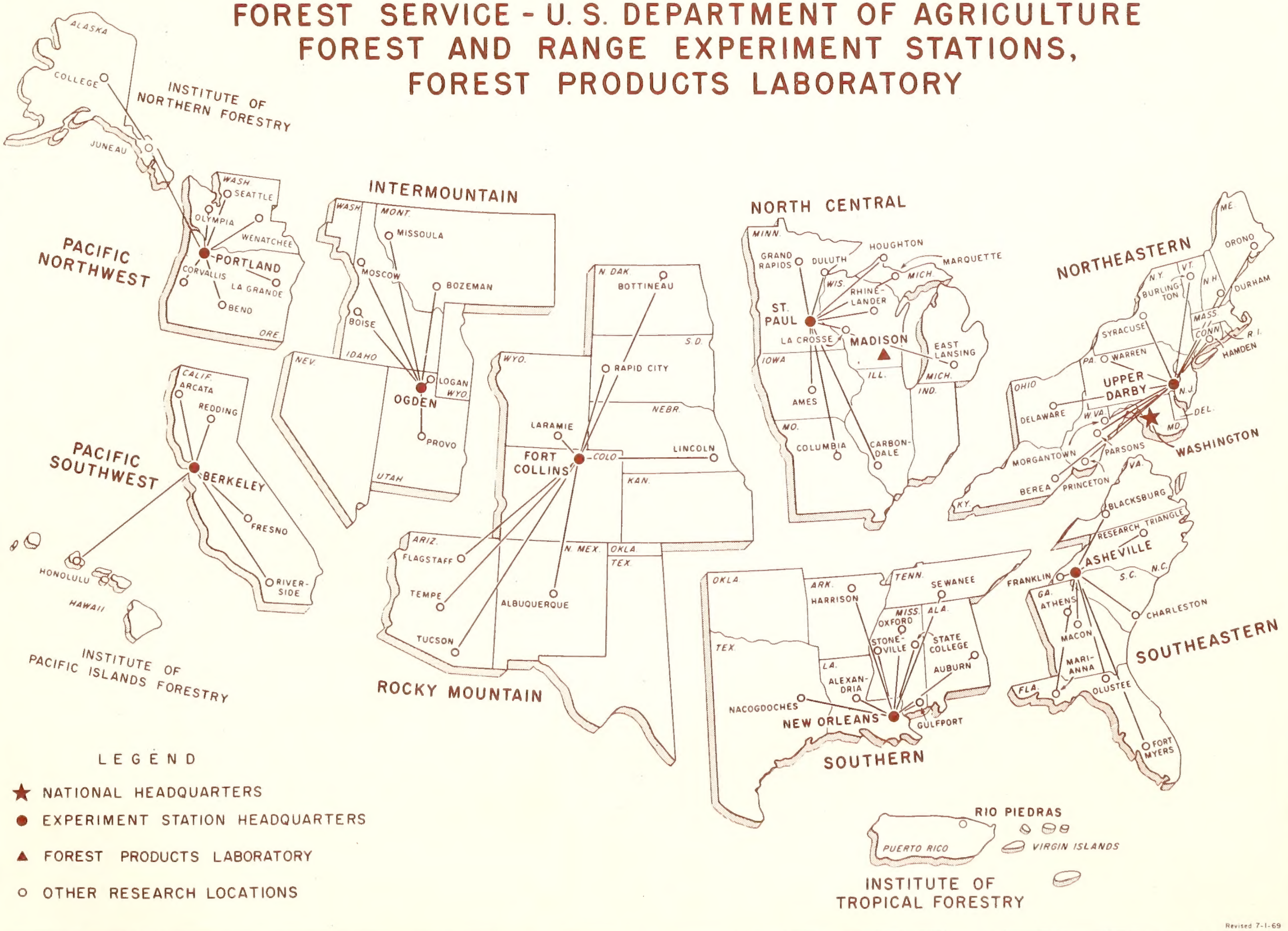

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
WASHINGTON, D.C. 20250

IN REPLY REFER TO
1380 (4000)

October 1, 1969

Dr. T. K. Cowden
Assistant Secretary
U. S. Department of Agriculture
Washington, D. C. 20250

Dear Dr. Cowden:

I am pleased to transmit to you this progress report of research by the Forest Service and our cooperators. This report serves many purposes. It provides you and other administrators in the Department of Agriculture with an overview of our research effort. It is used by the Forest Service, other agencies and our cooperators in research program coordination, development and evaluation. In addition, users of research accomplishments are provided a summary of the new knowledge and technology recently developed by Forest Service Research.

Research in the Forest Service is placing increased emphasis on new technology for improving environmental quality and producing multiple benefits from forests. We are also aware that the rush to use new technology bears the inherent danger of inadvertently disrupting entire ecosystems and even biomes and irreversibly damaging the environment for man, animals and plants. There is urgency in discerning, through research, the interrelated activities and natural laws that maintain healthy, enjoyable, and livable outdoor environments. A sound program of research closely tied to our National Forest System and State and Private Program gives us alternative ways to increase the efficiency of resource management, to reduce resource requirements, to maintain relatively stable prices and to create new rural investment opportunities, all without detriment to the environment.

Sincerely,

Edward P. Cliff

EDWARD P. CLIFF
Chief

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Forward

Forest Service research plans are coordinated through the U. S. Department of Agriculture's Office of Science and Education with research in other USDA agencies, with that conducted under the Hatch Act at land grant institutions and with forestry research under the McIntire-Stennis Act at schools of forestry. Coordination of research with other educational institutions, private enterprises, non-profit institutions and other public agencies is maintained mostly through direct contact between people of these organizations and those of the Forest and Range Experiment Stations. Federal, State, industry and university cooperation in solving mutual problems is achieved through cooperative agreements that provide for joint development and support of the research by the cooperators.

This report is arranged by research subject areas in order that the reader can go directly to the areas of interest to him. Each accomplishment is summarized in a single, short paragraph followed by an abbreviation denoting the Forest Service research unit best able to supply additional, detailed information and copies of the nearly 1100 publications listed. These units and the abbreviations used in keying the research accomplishments follow. Their locations are shown on the map in the inside front cover. For further information, publications, or service, any of these units may be contacted:

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Pacific Northwest Forest and Range Experiment Station
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INT - Director,
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RM - Director,
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Fort Collins, Colorado 80521

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North Central Forest Experiment Station
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NE - Director,
Northeastern Forest Experiment Station
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SE - Director,
Southeastern Forest Experiment Station
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Asheville, North Carolina 28802

SO - Director,
Southern Forest Experiment Station
T - 10210 Federal Building, 701 Loyola Avenue
New Orleans, Louisiana 70113

FPL - Director,
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Madison, Wisconsin 53705

ITF - Director,
Institute of Tropical Forestry, University of Puerto Rico
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Washington, D. C. 20250

TIMBER MANAGEMENT RESEARCH

TIMBER CULTURE AND ECOLOGY RESEARCH

Problems and Objectives

The broad field of silviculture includes the problems of growing and tending forest trees and stands from seed to sawtimber. It deals with reproducing forests both naturally and artificially, with intensive culture measures for increasing the yield and improving the quality of forest stands, with methods for evaluating and improving the productive capacity of forest soils, and with stand treatments required to perpetuate valuable species adapted to the site. Related to all of these problems are the basic physiological processes involved in tree growth and the ecological processes governing forest growth and productivity.

Major objectives of research are to develop improved techniques for:

1. Increasing the efficiency of timber production.
2. Reducing the shortage of high-value hardwoods.
3. Integrating timber production with other forest uses.

A. Site Evaluation and Soil Improvement

Soil and topographic variables can now be used to predict oak site index in Ohio and Indiana. In southeastern Ohio, surface soil depth, subsoil texture, aspect, slope position, steepness, slope shade, and tree age accounted for 81 to 84 percent of black oak tree height variation, tree age alone accounted for 54 to 60 percent of the variation. In southern Indiana, depth of surface soil, distance from ridgetop, slope steepness, stone, silt, and clay content, and tree age accounted for approximately 84 percent of the variation in tree height for black and white oak; tree age alone accounted for 37 and 34 percent of the variation. Site prediction tables developed from these two studies will enable foresters to determine site index in two additional sections of the oak region. - NC

Similar relationships between site index and soil and topographic factors have been developed for 10 commercially important species in the Georgia Blue Ridge Mountains. Site index was more closely related to topographic features than to soil characteristics. The most reliable predictors were those that influence climate and moisture supply, such as elevation, position on the slope, aspect, and slope steepness. - SE

In soils similar to those in the Blue Ridge Mountains of Georgia, the use of two to four soil pits per plot is required to estimate mean values of the properties most commonly measured in soil site studies. If soil series averages rather than plot averages are required, maximum efficiency is obtained with one or two pits per plot. Sample stratification on the basis of soil type does not appear justified. - SE

Redox potential--a measure of the potential to gain (reduction) or lose (oxidation) electrons--must be used with great care as an index of soil aeration conditions. In a recent study, redox potentials of a saturated forest soil were considerably decreased over a 25-day period of high temperature and the addition of organic matter. The activity of anaerobic soil micro-organisms seemed to be a dominant factor in the development of redox potentials, and the influences of temperature and organic matter were important only as they affected these micro-organisms. - SO

Lupine is of no value in stimulating the growth of pines on coarse, sandy soils. In this P. L. 480 project in Poland, lupine did not grow well on sands without fertilization, so that the hoped stimulation of pine growth did not materialize. Nor was there any increase in the nitrogen content of either the soil or the pine foliage. Good pine growth was obtained after fertilization, but lupines in combination with fertilizers did not significantly improve growth over that obtained with fertilizer alone. - WO

Subsoil fertilization may be required to encourage deeper rooting of yellow birch in soils low in calcium and high in aluminum. Split medium cultures--with nutrient-adequate humus as the upper medium and variously altered nutrient solutions as the lower medium--showed clearly that a lower substrate deficient in calcium will not support primary root development of yellow birch. Calcium deficiency also retarded stem and leaf growth. Further reductions in root and top growth were obtained when an aluminum toxicity was superimposed upon each macronutrient deficiency. - NE

Fertilization stimulates the growth of eastern cottonwood, sweetgum, water and willow oak, yellow-poplar, and sycamore. Experiments with each of these species throughout the South have shown that nitrogen appears to be the key element in most cases. Increases of as much as 65 percent in diameter growth, and 44 percent in height growth were obtained with pole-sized oak and sweetgum trees. And increases of up to 68 percent in height growth were obtained with sycamore seedlings. - SO, SE.

Pines will respond to fertilization on the Florida sandhills. Phosphorous is the element in shortest supply on sandhills soils, except where these soils are developed over phosphatic materials. Phosphorous applied in combination with nitrogen at a 1:1 ratio produced the greatest response. Phosphorous must be mixed with the soil in the rooting zone if the pines are to receive full benefit of the fertilizer. - SE

The productive potential of poorly-drained flatwoods soils may be increased considerably through drainage and/or fertilizer applications. Fertilization more than doubled the dry weight increment of slash pine seedlings growing on flatwoods soils that were low in phosphorous and nitrogen. Height growth was also increased by one-quarter in this Florida study. Flooding increased seedling mortality and decreased growth. Dry weight increment of flooded seedlings receiving fertilizer was 40 to 50 percent greater than unfertilized but flooded seedlings. - SE

The addition of nitrogen caused greater increases than all other macronutrients tested in slash pine sand culture experiments undertaken in Brazil under a P.L. 480 project. However, the higher concentrations of nitrogen reduced fiber length and cell wall thickness; cellulose content was unaffected. Calcium and sulphur also increased growth, and sulphur increased cellulose content. Fiber length and cell wall thickness were not affected by calcium, magnesium, or sulphur. - WO

Nitrogen fertilization appears to have high practical value on the extensive nitrogen-deficient sites in western Washington and Oregon. Nitrogen additions to a 35-year-old Douglas-fir stand in the Pacific Northwest increased height increment 62 percent and DBH increment 79 to 160 percent. Gross basal area increment was greater with heavier fertilizer applications, but snow breakage was also increased. Net production after 4 years tended to be greatest with the addition of 200 pounds of nitrogen per acre, but there are indications that heavier applications will have a longer lasting beneficial effect. - PNW

Fertilizer applications do not always produce increased growth. White pine trees in 30- to 40-year-old plantations in Maine, responded to potassium fertilization on a droughty, loamy soil developed on a glacial terrace but similar trees did not respond to any of eight different fertilizer treatments on a sandy loam soil of an alluvial terrace. These results emphasize the importance of soil conditions in response to fertilizer. - NE

Information now accumulating on the relation between foliar nitrogen and growth response of loblolly pine to fertilization in different environments will aid in the establishment of standards for forest fertilization. Nitrogen in needles of field-grown loblolly pine may range from 1.04 percent to 1.68 percent. In one study, nitrogen application to 9-year-old trees with needles containing 1.16 percent nitrogen increased diameter growth by 16 percent and height growth by 12 percent. Since soil and other environmental factors influence response to fertilization, a considerable amount of such data will be required to evaluate nutrient status and fertilization needs over a wide range of conditions. - SE

The need for fertilization can sometimes be determined from leaf color, size, or shape. Nitrogen, phosphorous, and potassium deficiency symptoms characteristic of yellow-poplar leaves have now been described and related to measured concentrations of these elements in leaf tissue. Two percent nitrogen, 0.10 percent phosphorous, and/or 1.0 percent potassium are usually the minimal adequate levels in leaves of yellow-poplar seedlings. Yellow-poplar seedlings are much more sensitive to the supply of nitrogen than to that of phosphorous or potassium, and they will probably respond to nitrogen fertilization when leaf tissue levels are below 2 percent. - SE

Descriptions of visual nutrient deficiency symptoms are also available for other species. Symptom descriptions and colored illustrations have recently been published for western larch. - INT

Symptom descriptions and color photographs have likewise been published for black walnut, eastern cottonwood, black locust, sweetgum, Scots pine, and pin oak. These symptoms may be used as a diagnostic tool in determining what elements are deficient, and the severity of the abnormality can sometimes indicate the relative degree of the deficiency. - NC

B. Artificial Regeneration

1. Seed production and handling. Seed fall in old-growth redwood stands is usually ample for regeneration. Fair to good cone crops were observed for 5 consecutive years during a study in northern California stands. And germination of the seed averaged 86 percent. Most of the seed was dispersed during the winter months. - PSW

In mixed upper slope conifer stands of the Pacific Northwest, a good cone crop can be found on one or more species nearly every year. Seven years of observations indicate that western white pine and noble fir produce good cone crops about every 3 years; and mountain hemlock also produces comparatively frequent crops. However, Pacific silver fir yielded only one good crop during 7 years. Some very prolific trees within each species produced up to 5 times as many cones as an average dominant tree. - PNW

Control of damaging insects may be necessary to increase production of viable acorns in the mixed oak stands of the southern Appalachians. During a 5-year study of acorn production, very few sound acorns ever reached the ground except during a bumper year. Although numerous acorns were initiated each year, the majority either failed to develop or were damaged by insects or animals. Insects caused the greatest damage, infesting 81 percent of all acorns produced during one year of the study. - SE

Fertilization of longleaf and slash pine seed orchards may more than double female flowering and substantially increase cone production. Such increases were obtained after fertilization of heavily-thinned natural stands in Louisiana during either March or May, using 1000 pounds per acre of 15-25-10 fertilizer. Lower rates of fertilization were less effective. Annual disking in June was necessary to reduce competition for the fertilizer. The increase in cone production more than repaid the costs of fertilization and cultivation in 3 of 5 years for longleaf and 4 of 5 years with slash pine, when reasonable allowance was made for the higher value of genetically superior seed. - SO

Fertilization increases seed size as well as the number of seed produced. Seed from fertilized western white pine trees were found to be about 20 percent heavier than seed from unfertilized trees. The heavier seed should produce more vigorous seedlings. - INT

Cherrybark oak acorns may not germinate if they are allowed to dry after collection. In an Illinois study, 2 days of air-drying retarded germination and more than 4 days of drying (to a moisture content of about 10 percent) prevented germination completely. For nursery use, cherrybark oak acorns should be collected immediately after seed fall, or collected directly from the trees. They should be sown immediately or placed in moist cold storage for later sowing. - NC

Seedcoat scarification may be a useful technique for improving acorn germination. A study of water uptake has shown that very little moisture is absorbed through the seedcoat, particularly for acorns with a heavy waxy coating, such as those of Nuttall and pin oak. Absorption through the seedcoat is somewhat greater for acorns with a thin waxy coat, such as northern red and cherrybark oak, but splitting or removing the seedcoat increased water uptake of all four species. With the seedcoat intact, acorns absorb moisture mainly through vascular openings in the cup scar. - SO

Proper handling techniques will improve the germination of black cherry seed. Recent studies in Pennsylvania show that seed cleaned of pulp, kept moist, and then stratified for 120 days prior to sowing will give 75 to 90 percent germination. Fresh seed needed a period of warm temperature to after-ripen before stratification. If the seed is to be stored for a year or more, it should be sealed in polyethylene bags and kept at 32° to 38°F. - NE

Loblolly pine seed should be dried to less than 10 percent moisture content before storage to minimize the degree of dormancy. A study in Louisiana revealed that germination value of seeds stored at moisture contents below 10 percent was unchanged after one year of storage, while germination value of seed between 10 and 18 percent moisture content decreased from 17. 2

percent to 13.7 percent. Seeds stored at levels above 18 percent deteriorated rapidly in storage. The increased dormancy of seeds stored at 10 to 18 percent moisture content seems to be associated with an increase in seed respiration coupled with a comparatively impermeable seedcoat. - SO

Slash and shortleaf pine seed can be stored for as long as 35 years with little loss of viability. Seed stored for that length of time at 9 and 10 percent moisture content and at 33° to 38°F. yielded 82 and 50 percent germination for slash and shortleaf pine, respectively. The ability to store seed from bumper crops will alleviate shortages during poor seed years and reduce costs by concentrating collections in years when seed are plentiful. - SO

X-ray photography can be used to examine the internal structure of southern pine seeds without destroying the seed. The radiographs may be used to study seed dormancy, seed anatomy, and--when the seeds are impregnated with a contrasting dye--seed damage and seed viability. The radiographs also provide a permanent record. - SE

Research on the biochemical factors controlling dormancy in tree seed showed that the glyoxyloate cycle is active in germinating Pinus pinea seed and is correlated with lipid breakdown. The study, conducted with P. L. 480 funds in Italy, indicated that the cycle is more important in seeds germinated in the dark than in the light. This same research also showed that the inhibition by aromatic compounds of enzymes extracted from plant tissues can be overcome by the addition of detergents and certain polymers. - WO

2. Nursery practices, seeding, and planting. Liquid fertilizers applied twice a year through the nursery irrigation system are recommended for production of Douglas-fir planting stock. These readily-soluble fertilizers are as effective as granular-type, slow release fertilizers, and they can be applied more cheaply. Comparisons of these fertilizers under several application regimes in a north-coast California nursery revealed no important differences in the size, weight, or top-root balance of 2-year-old seedlings. - PSW

When used as a packing material western redcedar shingle tow can be detrimental to conifer seedlings. Chemical compounds found in cedar wood, particularly thujaplicans, can depress root respiration or kill seedlings. Soil on the seedling's roots tends to absorb these compounds and moderate their influence. Although the use of shingle tow has probably not caused more than occasional seedling losses in the past, the use of alternate packing materials seems desirable. - PNW

Chemical baiting and use of endrin-treated seed, the commonly used technique for controlling coniferous tree seed losses to rodents, failed to provide control in high-elevation forests of the Cascades in Oregon and Washington. In two tests of seedspotting, satisfactory stocking was obtained only on spots protected by wire screens. Damping-off and insects also caused seedling mortality. More effective methods of protection will be required before seedspotting can be used to regenerate these upper slope forests. - PNW

Tree seedlings inoculated with mycorrhizae are better equipped to survive transplanting to poor sites in India than seedlings without mycorrhizae. Normally, mycorrhizae do not develop until seedlings are field planted and then, only slowly. Nursery efforts to develop mycorrhizae on nursery seedlings in that country are therefore needed. Fertilizer significantly affected the development of mycorrhizae in sand culture, with best development occurring at 65 ppm nitrogen and phosphorous and 19.5 ppm potassium under the conditions of this P. L. 480 experiment. Sporophores of suspected mycorrhizal fungi were isolated and their laboratory cultural requirements were determined. - WO

Arasan-endrin applications provide direct-seeded black walnuts with a fair degree of protection against small mammal depredation. The materials are most effective when applied as a slurry directly to the walnuts. Use of fiber fillers and application to the soil rather than to the nuts were less effective, as were other repellents (nicotine and selenium) tested. Although arasan-endrin did not limit pilferage to the desirable level of 50 percent or less, it did permit germination of 36 and 46 percent in years when untreated seed yielded 8 and 23 percent. - SO

Root system development of longleaf, loblolly, and slash pine seedlings varies with soil type. In a Louisiana study, seedlings tended to have fewer and shorter laterals in sand than in loam or clay. Surprisingly, plants in the clay had more extensive root systems than those in the loam. Inhibition of root development due to soil conditions does not appear to be a major factor affecting survival of southern pine seedlings. - SO

Planting slash pine seedlings to the depth of the terminal bud in droughty sandhill soils significantly improves early survival without having detrimental effects on tree height. Five years after planting, the deep-planted trees were one-half foot shorter than those planted at normal depth, but differences in height were no longer significant after 10 years. This South Carolina study also showed that low-grade stock does not grow as well as better grade stock, even though deep planting will enable it to survive adequately. - SE

Planted paper birch will survive and grow satisfactorily on old sites if sod competition is controlled. A series of studies in Maine revealed that survival and height growth were greatest for seedlings planted on a furrow slice, and least for those planted directly in the sod. Seedlings planted on scalped plots also did poorly. Mice and deer caused much damage to these seedlings, and should be controlled to insure survival of the plantings. - NE

Recent research showed that cottonwood seedlings--rather than cuttings--should be used for planting on Mississippi River Delta sites that are subject to flooding early in the growing season. One-year-old seedlings whose tops protruded above high water survived and grew significantly better than either short or long unrooted cuttings on flooding sites. However, cuttings should continue to be used on other sites because they are inexpensive, easy to procure, and they allow rapid expansion of genetic selections. - SO

Replacement of dead trees in southern pine plantations is usually unsuccessful. Analyses of replacement plantings in slash, loblolly, and longleaf pine plantations in Louisiana show that both survival and growth of the replacements were far inferior to those of the original trees. At pulpwood rotations of 30 to 34 years, replacement trees contributed too little to merchantable pulpwood volumes to justify their cost. Replacement planting was particularly unsuccessful when postponed until the second year after the original planting. - SO

Shade improves germination and initial establishment of white pine. In a direct-seeding study in Maine, heavy shade favorably modified the environment on a dry site, greatly increasing germination; light shade gave slightly better results on a moist site. Mortality of the new seedlings did not differ significantly among sites or shade treatments. - NE

Experience gained through 10 years of operational direct-seeding in the South has been summarized, and situations where it has not been consistently successful are described to help landowners avoid these pitfalls. Direct-seeding has gained wide acceptance. It has been used successfully on many diverse sites, some of which would be almost impossible to plant; and it is cheaper than planting, reducing costs by $15 to $20 per acre on the most difficult sites. - SO

Direct-seeding may also be used to establish pine stands in Tennessee's Cumberland Plateau. Seven years of investigations show that seedbed preparation is a more crucial factor in Tennessee than it is further south, because leaf litter builds up to greater depths there. This deep litter must be removed before broadcast sowing and hardwood leaves must be prevented from covering seed that have been furrow- or spot-seeded. Use of these direct-seeding techniques will facilitate the conversion of low-quality hardwood stands in these areas to more productive pine. - SO

Nonsprouting greenleaf manzanita brushfields in the Cascade Range of Oregon can be killed with a single aerial application of herbicide to clear the area for conifer plantings. Application of 3 pounds acid equivalent of 2,4-D per acre will kill the manzanita; application of 1.5 pounds acid equivalent per acre will usually release Douglas-fir seedlings from manzanita competition with a minimum of damage to the conifers. However, rabbit browsing is apt to be a problem after chemical brush control; where rabbits are prevalent, mechanical eradication by piling and burning should be considered. - PNW

Either slash or loblolly pine is equally suitable for planting on good sites in the South Carolina sandhills. Ten years after planting, these two species had outgrown ten other conifers included in a comparative trial. Redcedar and Arizona cypress showed promise as Christmas trees. This comparison confirms the usual recommendation that slash pine be planted on these Carolina sandhills, and suggests that loblolly pine may be an excellent alternative on the better soils. - SE

Red pine, Japanese larch, and European larch should be favored for plantings on the Allegheny Plateau of northwestern Pennsylvania. Examination of 35-year-old plantations revealed that these species have outperformed 6 other conifers and two hardwoods; some of the plantations have produced exceptionally high volume yields. Row-mixture plantations generally produced more board-foot volume than pure plantations since one of the species in the mixture usually was suppressed, providing a natural thinning for the other. - NE

C. Natural Regeneration

Amount of lodgepole pine regeneration on some areas may be related to the number of serotinous cones in the logging slash to serve as a seed source. On one area, in an Idaho study, 48 percent of the trees had predominantly serotinous cones, as opposed to only 23 percent on the other area. The numbers of seeds stored in cones on the two areas was estimated to be 1.8 and 0.8 million per acre, respectively. - INT

To be well within the area of shortleaf pine seed dispersal, no part of a clearcut opening should be more than 2.5 chains from the seed source. One-half of shortleaf pine seed fell with 66 feet of the trees bordering a clearcut area in an Arkansas study and 85 percent fell within 165 feet. Prevailing winds did not noticeably affect these dispersal distances. - SO

Small openings that promote snow accumulation and persistence may discourage natural regeneration of true fir and mountain hemlock, particularly where early winter snows occur before seedfall. Seed of these species commonly germinate in late-persisting snowbanks in the Pacific Northwest. Almost none of these germinants become established in the soil. Artificial seeding of these species on snow would also be unwise. - PNW

Seed-tree cutting can be used successfully to reproduce bottomland hardwoods in the Carolina coastal plain. Six growing seasons after an experimental cutting, enough desirable stems were present to form a new stand, and these stems were growing rapidly. The poisoning of stumps and residual vegetation to ready the site was very important for establishment and early growth of desirable seedlings. - SE

Shelterwood cutting provides excellent longleaf pine regeneration in the mountain and Piedmont provinces of Alabama. Burning for seedbed preparation greatly increases establishment, and caused no damage to the soil on steep slopes in this study. These findings will help foresters and landowners to regenerate mountain longleaf stands where climate, topography, and soils impose conditions different from those in the major coastal longleaf belt. - SO

Advanced reproduction may provide adequate Engelmann spruce-subalpine fir regeneration in the central Rocky Mountains, even if new seedlings do not become established. In a study of strip cutting in Colorado, new reproduction was scarce, apparently as a result of poor seed supply and competition from ground vegetation. However, advanced seedlings provided satisfactory stocking for a new stand on all study areas. Subalpine fir seedlings were more numerous than were Engelmann spruce seedlings. - RM

Stand openings in true fir forests of California should be no wider than 3 chains (200 feet) to take advantage of the beneficial effects of shading on seedling establishment. During a study of the daily movements of ground shadows, shade in clearcut strips was less than expected. Patterns of sun and shade varied from theoretical expectations because of variation in tree size and spatial distribution, crown shape, and crown density. - PSW

To reproduce black spruce and avert succession to brush on lowland areas in Minnesota, residual vegetation should be killed as soon as possible after clearcutting. Brush that develops when these spruce swamps are clearcut comes from the vegetative reproduction of shrubs already present at the time of logging, and not by invasion from surrounding areas as previously believed. - NC

Soil moisture needed for successful regeneration of conifers in the Cascades can be markedly increased by removing or killing competing vegetation. In a study in southwestern Oregon, sites with competing vegetation had much higher soil moisture tensions than sites where the vegetation had been removed; during the driest period of the summer, tensions at the 6-inch depth usually averaged 15 to 25 atmospheres with vegetation versus 2 to 8 atmospheres without vegetation. - PNW

Northern red oak is adapted to even-aged management because northern red oak seedlings grow best in full sunlight. In a North Carolina study, seedlings grown one season in full sunlight were taller, had more and thicker leaves, and were generally in healthier condition than seedlings grown under three levels of shade. - SE

Differences in canopy density and nutrition apparently account for most of the differences in understory vegetation in alder, conifer, and mixed alder-conifer communities in coastal Oregon. Vegetation analyses of such communities revealed that shrubby species were confined mainly to the mixed pine-alder stand where they formed a dense layer. Herbaceous plants were best developed in the alder and mixed stands and ground-dwelling mosses and lichens were most numerous in the mixed and conifer stands. These results demonstrate the differing influences of tree species on the composition of understory plant communities, a significant matter in forest regeneration and environmental forestry. - PNW

Initial density of aspen root suckers after clearcutting is not critical to produce adequately-stocked, rapidly-growing stands. Mortality in dense stands reduces the number of stems rapidly so that the size of crop trees at 15 years of age is essentially the same over a wide range of initial densities. Densities ranging from 1,000 to 10,000 one-year-old stems per acre will produce an adequately-stocked stand. - NC

Understory sugar maple seedlings and saplings can be relied upon to produce good merchantable stems under uneven-aged management. Although many of these understory stems have crooks and flat-topped crown, stem quality improves after selection cutting in the overstory. To an appreciable extent, flat tops produced new leaders and minor crooks were overgrown in trees examined in a West Virginia study. - NE

A mathematical model has been developed that will permit computer simulation studies of natural birch regeneration. The model provides an analytical expression of the chain of events that occur in the regeneration process--from the formation of the flower to the development of an acceptable stem. The process permits estimation of the probabilities associated with the expected number of seedlings that would be obtained under any set of circumstances. The estimates of seedling number could be used to evaluate the benefits, of, or the need for, supplemental cultural measures. NE

D. Multiple Use Silviculture

Almost any type of timber harvest produces enough browse to support a normal population of deer in Appalachian hardwood forests. A study in West Virginia revealed that harvest cuttings result in enough stems of preferred species to support at least 13 deer per square mile, without appreciable damage to tree reproduction. Special cuttings for deer browse production are not necessary unless it is desired to maintain a larger deer herd. Thus, deer and timber can be managed together without serious conflicts of interest. - NE

Cleaning operations to accelerate growth of selected crop stems in sapling hardwood stands also produce deer browse. In a North Carolina study, the number of stems suitable for browsing was significantly increased after cleaning; and basal area of the crop trees increased by 230 percent in the cleaned area, but only 140 percent in the uncleaned area. These results provide further evidence that timber and deer may be produced together in Appalachian hardwood forests. - SE

Quail and timber can also be managed together in the pine forests of the southern coastal plain. Many management techniques developed to increase wood production--such as prescribed burning--also favor this bird. Landowners can therefore increase the quail population on their lands to obtain hunting benefits, without reducing timber production. - SO

An adequate, representative natural area system is essential for continued progress in scientific forestry, as well as in other fields of biological research. But lands suitable for natural area use are quickly vanishing. A summary of the value and use of natural areas and a set of criteria used in the selection of such areas have recently been published to encourage foresters to maintain the leadership in efforts to build a natural area system adequate for the Nation's needs. - PNW

E. Stand Improvement

Net growth of young white oak stands is optimum after thinning to 50 to 60 percent stocking, and individual trees increase in diameter rapidly at these densities. In a comprehensive study of oak growth and yield in 30-year-old stands in Iowa and Kentucky, gross basal area growth and cubic volume growth were little affected within the range of stocking from 50 percent to maximum stocking. Greatest net basal area and cubic volume growth occurred between about 50 and 60 percent stocking and were 15 and 30 percent higher, respectively, than growth at 100 percent stocking. Use of these thinning recommendations will permit significant reductions in oak rotation ages. - NE

Thinning of formerly stagnated sweetgum stands to a residual density of 70 square feet of basal area per acre will allow maximum growth of the better stems. Thinning to 90 square feet produced comparable total growth, but it was spread over weaker and less desirable trees. And the site potential was not fully utilized when only 55 square feet were left. This study stand in Louisiana contained about 120 square feet of basal area before thinning, in trees with an average d.b.h. of 10 inches. Growth of the unthinned stands was about two-thirds the growth of thinned stands because of mortality. - SO

After an initial thinning, stands of northern white-cedar can be rethinned to a basal area at least as low as 90 square feet per acre without diminishing gross growth or increasing mortality. Gross growth, net growth, ingrowth, and mortality were all independent of stand densities ranging from 90 to 225 square feet per acre in a Wisconsin study. Diameter growth was greatest on the larger trees in the lower density stands. Thinning in similar stands should raise quality of the final harvest as well as increase total yield. - NC

Thinning of dense ponderosa pine pole stands in northern Washington promotes diameter growth and wood production of trees that will reach usable size. Trees spaced 13, 19, and 26 feet apart grew at the rate of 2.0, 2.6, and 3.2 inches in diameter per decade. Comparable trees in unthinned plots grew only .63 to .73 inches per decade. There was some reduction in total wood production at the wide spacings, but this reduction occurs early in the rotation while the trees are still small. Thinning also increased forage production. - PNW

Thinned ponderosa pine trees began diameter growth earlier in the year and made more total growth than unthinned trees in a South Dakota study. The 3- to 5-week earlier start of thinned trees meant that they were growing actively through a greater part of the period of most abundant moisture. Although height growth was also greater on the thinned trees, there were no differences in the timing of this growth. If the greater diameter growth observed in the study could be maintained by regular thinnings, it should be possible to grow trees to sawtimber size in the Black Hills in a shorter time than now needed. - RM

Near maximum growth and yield of longleaf pine stands may be obtained by periodically thinning to medium stand densities. Twenty-five-year results of a study in southwest Alabama suggest that total yields tended to increase with increasing density of the residual stand, but that yields for the medium densities averaged only slightly less than yields for the highest densities. Since diameter growth of individual trees decreased with increasing residual densities, thinning to medium density (55 to 65 square feet of basal area per acre) should optimize value yield by enabling managers to reduce their investment in growing stock and promote the growth of larger, more valuable products. - SO

Glaze storms may cause severe damage in heavily-thinned loblolly pine stands on the Georgia Piedmont. Yield from 19-year-old stands row-thinned or thinned heavily from above was reduced to between .50 and .75 cords per acre per year, while similar stands thinned selectively from above suffered little damage and yielded 1.0 to 1.4 cords per acre per year. Glaze storms are common in that section of the Piedmont. - SE

Row thinning of 15- to 20-year-old loblolly pine stands in eastern Maryland will increase growth of crop trees and shorten the time required to grow sawtimber. Ten years after removal of every other row of trees, the crop trees had grown 0.8 to 0.9 inches more in d.b.h. than unthinned crop trees, and live crown lengths and crown ratios were larger than on unthinned trees. Removal of every third, fourth, or fifth row produced proportionately less growth than removal of every other row. Total stand volume growth was higher in the unthinned stand than in the thinned ones, so that thinning is recommended for sawtimber but not for pulpwood production. - NE

Comparisons made in several studies have shown that early selection thinning is more effective in stimulating stand growth than row thinning. It is more costly and time consuming, but costs are offset by the value of the added growth. Trees in selectively cut plantations are of better quality than those in row-thinned stands. However, row thinning is well adapted to mechanical harvesting. Conventional logging is also facilitated, but the difference in production costs between the two methods are small. Stand conditions, management objectives, and economic factors will determine the best method to use in specific situations. - SO

Slash pine trees may attain 35 feet in height and 8 inches in diameter in only 9 years under intensive culture. In a Florida study, selected slash pine clones planted at wide spacing responded to irrigation, fertilization, disking, and cover cropping; the most effective treatment combination was irrigation plus cover cropping both with and without fertilization. Flower and cone production was also increased after fertilization. The 24 clones varied considerably in their response to cultivation; for example, trees of some clones grew up to 50 percent more when fertilized than when not fertilized while other clones were unaffected by fertilization. Variations such as these suggest that it is feasible to develop trees which--when cultivated--will grow rapidly, flower early and prolifically, and resist insect attacks. - SE

Repeated foliage sprays are necessary to kill some brush species in southwest Oregon. Repeated sprays with 2,4-D, 2,4,5-T, 2-(2,4-D), and amitrole on 13 troublesome shrub species showed that four are easily killed with one spraying, two needed a second application, and six others required three treatments to kill a high percentage of the shrubs. One species proved highly resistant. These results can be used to prejudge effectiveness of aerial spraying for all 13 species. - PNW

Application of 2,4-D emulsifiable acid will release desirable reproduction from Japanese honeysuckle. In a Maryland study, late fall applications were found best for release of hardwoods; late summer or early fall applications were better for release of pines. These treatments gave adequate control of the honeysuckle with minimum damage to tree reproduction. For site preparation in an area where reproduction is not yet established, a mixture of

2,4-D--picolinic acid applied during spring or early summer will provide more effective control of the honeysuckle. - NE

Benzene hexachloride--a pesticide--accumulates in the cell walls of loblolly pine and sweetgum seedlings and is not detoxified to any appreciable extent by enzyme systems in these woody plants. In controlled tissue experiments at the University of Georgia supported by a Forest Service grant, concentrations of benzene hexachloride as low as 0.5 ppm severely inhibited root extension of excised loblolly pine embryos. However, in forest soils, levels as high as 250 ppm had no adverse effect on either species. - WO

Silvicultural control of dwarf mistletoe in heavily-infected ponderosa pine stands requires clearcutting of the original stand. In an Arizona study, cutting over 90 percent of the infected trees was ineffective; the volume infected tripled within 10 years and the heavily cut stands suffered much windthrow. In lightly infected pole and sapling stands, adequate control is achieved by cutting trees with bole infections and pruning or cutting those with branch infections. - RM

F. Animal Damage

When bears strip the bark from trees to feed on the sapwood, they seem to choose species with high sugar content. Chemical analyses of trees in western Washington have shown that Douglas-fir--the species most preferred by bears--contained the highest sugar content; sugar concentration in the other species was progressively lower, corresponding with decreases in the bears' preference. However, feeding varies widely among locations, indicating that other factors must be studied to understand bear behavior adequately. - PNW

Douglas-fir is also a preferred food of black-tailed deer in Washington and Oregon. Recent studies have shown that browsing can be expected until the seedlings grow out of reach of deer, because this species is available during winter when green forage is least available. However, deer also browse Douglas-fir seedlings during the period of active growth in the spring, even though other vegetation is available at that time. - PNW

G. Growth Requirements

Dry weight of foliage in 52-year-old stands of longleaf pine in Alabama is closely related to basal area growth. In stands with densities ranging from 9 to 45 square feet of basal area per acre, an average annual production of about 2.3 thousand pounds of needles was required to sustain a basal area increment of 1 square foot per year. Growth per unit weight of foliage appeared to decline with increasing stand density. Data such as these will enable comparison of the productive potentials of different species on varying site conditions. - SO

Rate of net photosynthesis in different environments varies widely among species. In a study of six conifers grown at four locations relative to the border of a Douglas-fir stand in Washington, highest average daily rates of net photosynthesis in hemlock, grand fir, Sitka spruce, and Douglas-fir occurred in the partially-shaded area near the outer margin of the stand; rates were lower inside the stand border than outside. With Scots pine and noble fir, highest rates occurred on open, fully exposed areas. These latter species, apparently lost less moisture than the other species. These results help explain the mechanisms by which the various species are adapted to different environments. - PNW

Red alder's rapid growth rate may be due to its greater capacity to utilize high light intensities and the fact that it has more leaf area per unit leaf weight and greater total leaf area per seedling than associated conifers. In a study of photosynthesis under various light intensities, the conifers--western hemlock, Douglas-fir, and Sitka spruce--reached maximum photosynthetic rates at lower light intensities than alder. When grown under shade, the four species tended to be similar in photosynthetic rates, suggesting that alder's faster growth is limited to high light situations. - PNW

Dormant sweetgum seedlings can be forced to resume growth by application of either continuous chilling or long photoperiods. In a Mississippi study, dormant plants given 1200 to 1600 hours of continuous chilling rapidly resumed growth under greenhouse forcing conditions; and long photoperiods had a similar effect. Plants maintained under short days or plants that had not had at least 600 hours chilling reset apical buds after a short period of growth. Plants from different geographic sources varied in the amount of chilling required. - SO

Areas subject to periodic flooding in the Pacific Northwest can be managed for western redcedar and lodgepole pine but not Douglas-fir. In a study of tolerance to artificial flooding, western redcedar and lodgepole pine were the most flood tolerant, Douglas-fir was extremely intolerant, and Sitka spruce, western hemlock, and red alder were intermediate. Summer flooding was more damaging than winter flooding on all species. Regeneration expenses will be minimized and scenic beauty enhanced if these recommendations are followed. - PNW

Changes in leaf-water deficit that occur with changes in soil moisture can be explained more clearly by reference to a soil moisture-retention curve than they can without the curve. Concurrent measurements of soil moisture and leaf-water deficit in slash pine, sand pine, longleaf pine, and turkey oak seedlings grown in a sand soil revealed that leaf-water deficit was nearly independent of soil moisture when soil moisture tension was low (soil moisture high). As soil moisture tension increased above about 4 atmospheres, leaf-water deficit increased markedly with small decreases in soil moisture. Use of these relationships should facilitate study of the effect of soil moisture on tree growth. - SE

Terminal shoot growth of sycamore, sweetgum, and Nuttall oak seedlings decreases when leaf-water deficits reach 6 to 9 percent of leaf-water-holding capacity. This point was reached after 9 days without addition of water in a clay soil and 3 to 5 days in a silt loam. Soil moisture tensions at this stage ranged from 12 to 17 atmospheres in the clay, and from 1 to 3 atmospheres in the silt loam. Terminal growth stopped completely after 13 to 15 days without water in the clay or 11 days in the silt loam; average leaf-water deficits at this time varied widely among species. - SO

The seasonal height growth of cottonwood trees in southern Illinois is closely related to minimum air temperatures. In a study of seasonal growth patterns, most trees started height growth during the last week of April, and half of them were still growing after the middle of September. Those trees that continued growing late in the season made more total growth than those that stopped early. Cessation of growth appeared to be under strong genetic control. - NC

Seasonal height growth of various upper slope conifers in Oregon begins and ends at different times, and the several species are affected differently by annual fluctuations of climate. Lodgepole and western white pine began growth earlier than any other species, and their growing season was longer than any other species except western redcedar, which had the longest growing season of all species studied. Total height growth of Pacific silver, subalpine, and noble fir, western hemlock, and western redcedar was related to current weather conditions. This knowledge will facilitate timing of cultural treatments dependent on stage of growth and should aid in the selection of species for locations with unusual climatic conditions. - PNW

Trees in subarctic forests have adapted to growth under a very short growing season by an increased rate of cell division. In a study comparing the cambial activity of a 50-year-old Alaskan white spruce with a similarly aged and sized spruce in Massachusetts, it was found that rate of tracheid production was about twice as high in the Alaskan tree as in the New England tree. Most of this difference was due to rate of cell division. Thus, the major differences between the two regions are that the season for cambial activity is about half as long in Alaska, but the rate of cell division is about twice as fast in Alaskan trees. - PNW

The production of thick-walled latewood xylem tracheids begins as the current season's needles mature in red pine. Pioneering studies in Wisconsin show there is less demand for photosynthate in the new shoot and a high rate of photosynthesis in the whole plant at the time new needles mature; thus a sharply increased amount of photosynthate becomes available for wall synthesis at that time. - NC

The hormone IAA apparently affects the incorporation of sucrose in the walls of cells derived from the cambium in a complex way. In concentrations of 10 mg/l, it decreased incorporation into the cell walls of sycamore stems, and at 50 mg/l it increased incorporation in comparison with controls which received no IAA. Galactose and lignin were the cell wall constituents significantly affected by IAA. Incorporation into lignin was increased when concentrations of available sucrose were high, but incorporation was either unaffected or decreased at lower sucrose concentrations. - NC

Pioneering studies of the pattern of incorporation of cell wall constituents are improving our knowledge of wood formation. Although the cellulose/hemicellulose ratio within the secondary walls of red pine tracheids of different ages remains fairly constant, the proportion of different hemicellulose sugars changed with tracheid maturity. Lignin production increased from the outer wall to the area nearest the lumen. Maximum polysaccharide production occurred during the formation of the outer layers of the secondary wall. Data collected in this study suggest that the outer wall layers were deposited rapidly and with considerable pore space. - NC

Carbon dioxide is incorporated into certain terpene compounds of Monterey pine through a six-carbon intermediate, mevalonic acid, then to neryl pyrophosphate, and eventually to a ten-carbon monoterpene. All of the biochemical intermediates are not known, but investigations under a P. L. 480 project in Chile indicate that terpene pathways in trees are similar to formation of cholesterol in mammals and of carotene and rubber in higher plants. The identification of the new compound neryl phyrophosphate as an intermediate in terpene synthesis is an important step in understanding the biosynthesis of many compounds. - WO

The amounts and types of hormone-like growth regulating substances present in tree leaves, buds, and seeds varies with species, stage of growth, and age and vigor of the tree. Many new growth regulating substances were isolated in a systematic survey of growth regulators conducted under a P. L. 480 project in Poland. Among the many findings of this project is the fact that the common gibberellin of herbaceous plants (commercial GA_3) does not occur in pine tissues, but that other gibberellins do. Another finding is that some growth substances that occur in young, vigorous specimens are not present in old or slow-growing trees. These findings open the way for more detailed investigations of the role of growth regulators in forest trees. - WO

Intraspecific differences in rooting ability of cuttings exist among trees of pitch pine and European white cottonwood. In a Korean P. L. 480 project, biochemical characteristics found to be associated with good rooting ability were: high carbon/nitrogen ratio due to low nitrogen level; low level of amino acids; greater stimulation of root initiation by two growth promoting substances; less inhibition of root initiation by an unidentified inhibitor; and synergistic activities of the two growth promoting substances with IAA. - WO

H. Silvicultural Systems

Upland hardwoods in the central United States respond best to even-aged silvicultural systems for timber production. Results of many years of research in this hardwood region have been summarized in a handbook for forest managers and landowners. It recommends clearcutting for regeneration, regular thinnings during the rotation, and suggests ways to improve stand diagnosis and prescription. This information will help forest managers to grow full yields of the highest value products a particular site can produce. - NE

Shortleaf pine can be managed profitably in the Missouri Ozarks. Nineteen-inch trees can be grown in 70 years and pine stands will produce 40 percent more volume than oaks where the black oak site index ranges from 45 to 65. A summary of the site requirements, regeneration, protection, growth, and yield of shortleaf pine in this region is now available. It includes analyses of how rotation length, site quality, treatment costs, and value of products harvested will affect the profitability of managing pine in Missouri. NC

Greatest yields from eastern redcedar will probably accrue from sawtimber rotations with intermediate thinnings for posts. However, post production is maximized by the maintenance of dense stands. Grazing and fire should be excluded from eastern redcedar stands and all hardwoods should be eradicated. These and other silvicultural recommendations for eastern redcedar have been published in a guide that should encourage management of this species for supplemental income on many farms in the mountainous areas of Arkansas, Missouri, Tennessee, and Kentucky. SO

Red alder is the major hardwood of the Pacific Northwest; it is important both as a source of wood and for its soil-improving properties. Proceedings of a two-day symposium of the Northwest Scientific Association, published by the Forest Service, brings together information on all aspects of alder biology. This reference work will be of exceptional value to scientists and land managers concerned with alder management and its role in forest ecosystems. PNW

Logging costs should not affect the choice of cutting method in young-growth mixed conifer stands of California. In a study of logging costs and production rates, neither varied significantly with cutting method. Overall logging costs for clearcutting, seed-tree cutting, single-tree selection, and group selection ranged from $10. 90 to $11. 75 per thousand board feet. - PSW

A Spanish-English forestry terminology book, published as a result of a P. L. 480 project in Spain, will contribute to international cooperation in forestry education and practice. The book contains an alphabetical list of 7,000 English forestry terms, followed by the Spanish equivalent. It also has an alphabetical list of the Spanish terms followed in sequence by the Spanish or Portuguese equivalent used in different Latin-American countries, then the English equivalent, then the definition in Spanish. A final section contains an alphabetical list of the Latin-American terms, the country in which used, and the Spanish equivalent used in Spain. - WO

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TIMBER MEASUREMENT AND MANAGEMENT PLANNING RESEARCH

Problems and Objectives

Intensive management of the commercial forests of the United States requires dependable, low cost methods of measurement of the contents of trees and stands, and more reliable prediction of future growth, yield, and quality of forest products. Productivity of forests, both in quality and quantity, varies markedly according to stand density, site quality, tree age, and species composition. Important forest regulation problems involving levels of growing stock, cutting budgets, and rotation lengths must be solved. With better information about the response of forests to various cultural practices, more attention must be given to planning and decision-making problems in order to guide management of large public and private timber holdings.

Major objectives of this research are to develop more efficient methods to:

1. Measure the contents of trees and stands.
2. Predict growth and yield of forest in response to various forest management practices.
3. Determine optimum solutions to such management planning problems as allowable cut, rotation ages, and levels of growing stock.

A. Growth and Yield of Forest Trees and Stands

Saligna eucalyptus trees planted in Hawaii have demonstrated remarkably rapid growth, reaching 72 feet in height in 5 years. Height growth was unaffected by spacing, but diameter growth was greater on trees planted at wide spacing. Average d.b.h. ranged from 6.2 inches at 8- by 8-foot spacing to 7.9 inches at 14- by 14-foot spacing. Average d.b.h. of the dominant and codominant trees at the same spacings was 7.5 inches and 8.9 inches, respectively. - PSW

Overall average annual net growth rate for extensively-managed spruce-fir stands in Maine was estimated as 41.9 cubic feet per acre, about 1/2 cord per acre per year. Net growth was greatest in stands with the highest proportions of softwood species. These growth data provide a reliable estimate of natural stand growth in the region over the past ten years and they serve as a basis for management planning. - NE

Douglas-fir generally exhibits more rapid juvenile height growth than western white pine and noble and Pacific silver fir on the upper slopes of the Cascade Range of Washington and Oregon. In a study of seedling development in recently-cleared areas, silver fir grew slowest of the four species measured. Data accumulated on the number of years required for each species to reach breast height will facilitate total age determinations from increment core counts at breast height. - PNW

B. Forest Measurement

To keep tree height measurement errors within ± 5 feet, at least 4 trees should be measured; to keep measurement error within ± 2 feet, at least 25 trees need to be measured. These results were obtained with northern hardwood trees in New Hampshire, using tape measurements of felled trees to check the accuracy of previous Haga altimeter estimates. - NE

Readings made with Barr and Stroud dendrometers now can be easily field-checked with the use of a calculator developed especially for this purpose. The calculator consists of a set of scales that can be pasted onto a slide rule. - SO

A new technique of volume table construction has been developed that makes consistent volume estimates possible for any combination of product units, utilization limits, and size classes of products. The method involves the fitting of a curve or equation that describes the average tree profile, and use of the resulting estimates of upper stem diameters to calculate volumes in any desired units. Tables so constructed will be consistent among themselves, and others can be prepared as needed from the taper curves. Although the technique was developed with red alder, it should be applicable to other species. - PNW

Volume tables and associated point sampling factors for loblolly and shortleaf pine have now been published for plantations on old-fields in Tennessee, Alabama, and Georgia highlands. These tables provide the basic mensurational data necessary to estimate total and merchantable cubic-foot volumes both inside and outside the bark, to various top diameters. The tables may be used by measuring diameters and heights of trees counted on a point-sampling cruise. - SO

A comprehensive computer program has been prepared to calculate volume, surface area, and length of tree boles from sample data. Volume estimates can be obtained in cubic feet, or in board feet Scribner or International log scale. A major benefit of this program is its ability to calculate volume deductions from measurements of interior defect obtained by destructive sampling of felled trees, thus providing an accurate method of estimating merchantable volume. - INT

A method of determining slope and aspect from elevation data has been developed for computer use. Computations for a particular point are accomplished from a matrix of elevations surrounding it. The system makes it practical to obtain all three types of information from maps or aerial photographs, whereas the cost of coding slope and aspect data would normally be excessive. - PSW

A linear equation has been derived that will permit partitioning of stand density index to describe stocking by species or quality classes. The index for each component can be added together to get total stand density index. A closely-related expression for grand fir stocking is also given that retains the merits of the equation above, but is more nearly proportional to the growth of individual trees. These measures of stocking can also be expressed in units proportional to the degree of site occupancy, increasing their value to forest managers. - INT

Site index curves for northern hardwoods--developed in Vermont and New York--can be applied in New Hampshire if minor corrections are applied for certain species and stand ages. These curves for yellow birch, paper birch, white ash, sugar maple, and red maple provide a sound basis for estimating site index of these species. - NE

The number of samples required (or the sampling rate) for desired levels of accuracy can now be read from charts, eliminating the need for calculation. Use of these charts requires an estimate of the total numbers in the population and the coefficient of variation. The charts were prepared as an aid in sample log scaling, but they can be used in many other sampling problems. - PNW

The limits of utility of conventional regression procedures have been derived mathematically for situations in which the estimators of variances (required for construction of confidence intervals for regression coefficients) may be biased due to correlation of the sampling errors. The results may be applicable whenever observations that are spatially or temporally dependent are collected. - SE

C. Management Planning Procedures

A computer program has been prepared that simulates the management of even-aged forest stands using Black Hills ponderosa pine to illustrate the method. Changes that may be made in the model forest include tree growth, harvest cuts, periodic thinnings, random catastrophic losses, and management objectives. Results are presented as changes in board-foot and cubic-foot volume and money value. Simulation studies with this program will enable comparison of future outcome of numerous silvicultural alternatives, thus providing the knowledge on which sound management decisions can be based. - RM

Yield tables for stands managed in various ways can be prepared rapidly with two new computer programs prepared for this purpose again illustrated with Black Hills ponderosa pine. One program calculates the increases in stand diameter resulting from various intensities of thinning; these are then used in the second program to compute and print a yield table. Large numbers of tables, each based on a specified set of alternatives, can be computed and printed at a cost of only a few cents each. Such tables permit comparison of various management alternatives, and serve as a basis for management decisions. - RM

Multiple-product yield estimates have been developed for slash pine plantations in Georgia and Florida to help managers maximize financial returns. These estimates permit for the first time cost and return comparisons for a variety of products, spacing, and age, providing a tool that will enable selection of spacing that best meets the product or financial objective of the landowner. - SE

Comparisons of the expected value growth of five 70- to 80-year-old ponderosa pine stands in California with the costs of holding the land and the growing stock suggests that replacement of all 5 stands would be financially desirable if stumpage prices remain constant. If stumpage prices increase 25 percent during the planning period, two of the five stands should be retained. The method of analysis used in this study permits the forest manager to review the growing-stock assets of each land management unit to determine which areas offer prospective earning-rates that fall below an acceptable level; such stands should be replaced to improve the productive efficiency of the invested capital. The method described can be used for planning in other management situations or in other forest types. - PSW

Yellow birch trees cannot be grown beyond 22 inches d.b.h. in New England without sacrificing rate of value increase. And, where surface defects rule out the possibility of top-grade saw or veneer logs, a maximum size of about 18 inches is more reasonable. These conclusions were reached in a study of yellow birch financial maturity in which the expected rate of value increase was calculated for trees of various sizes, growth rates, grades, and merchantable heights. These data provide a sound economic basis for determining the point at which trees or stands cease to earn an adequate return and should be cut. - NE

The probability that a tree will improve in grade was the major factor affecting financial maturity of northern red, white, and chestnut oak. Trees that improve in grade earn high interest rates regardless of their other characteristics. These financial maturity data for the oaks are based on tree-growth and tree-quality data collected in West Virginia. - NE

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FOREST GENETICS RESEARCH

Problems and Objectives

Genetic improvement of forest trees is one of the most promising approaches to increasing the efficiency of timber production, improving timber quality, and reducing pesticide hazards. Trees bred for rapid growth, good form, desirable wood quality, and pest resistance are urgently needed in reforestation programs. Improved trees must be provided for planting under intensive culture in order to meet future timber needs.

Major objectives of the research are:

1. To determine the degree of inherent variation of important traits.
2. To develop effective hybridization and breeding schemes for improving these traits.
3. To devise the most efficient methods for mass producing superior trees.

A. Identification, Classification, and Distribution of Forest Trees

A study of 72 native stands of *Juniperus* located in the Missouri River Basin of the central and northern Great Plains disclosed that the population consists of two species, *J. scopulorum* and *J. virginiana*, with an introgressive trend between the southeast and the northwest. A group of hybrid values indicating F-1 types was identified in a north-south zone of the Basin. The trend toward *J. scopulorum* on the west side of this zone was more rapid than the trend towards *J. virginiana* on the east. The available evidence suggests that the *Juniperus* population in the Missouri River Basin evolved from *J. scopulorum* rather than from introgression between *J. scopulorum* and *J. virginiana*. - RM

A quantitative lipid extraction technique was perfected to assist in the analysis of juniper populations. This chemo-taxonomic technique may have wide application in plant taxonomy. Crude lipid extracts were obtained from juniper cone pulps and analyzed by infra-red spectrophotometry. Absorption spectra varied quantitatively and could be correlated with morphological and geographical distribution of sampled populations. - RM

Recent plant exploration of the northern Great Basin has contributed much needed information on the distribution of the Pinaceae in this region and has extended the ranges of several conifers. These include limber and white bark pines in northern Nevada, and Douglas-fir in southwestern Idaho.

Contemporary species distribution, in conjunction with fossil evidence, suggests that the highly discontinuous and sporadic distribution of the Pinaceae in this region may be the result of events during the Pleistocene epoch. PSW

The native trees of the Hawaiian Islands are unique--different from those everywhere else in the world. Many species are rare; a few are already extinct. Five of the important native species are: *Metrosideros coleina* (lehua) of the myrtle family, *Acacia koa* (koa) a legume, *Santalum Freycinetianum* (sandalwood), *Aleurites moluccana* (candlenut) of the sponge family, and *Cibotium menziesii*, a tree fern. Distinctive Hawaiian names for most native trees show that the first settlers were good naturalists. Modern inhabitants should take the necessary steps to save rare and endangered species from extinction. - WO

Two new pinyon pine varieties from Arizona have been described: *Pinus cembroides* var. *bicolor* and *Pinus edulis* var. *follax*. *Pinus edulis* var. *follax* has no outstanding characters of economic value. *Pinus cembroides* var. *bicolor* could become a popular Christmas tree in the Southwest. The bicolored needles, green and white, are particularly attractive. - WO

A fifth species of *Pinus*, *P. hartwegii*, has been reported from Honduras near the southern limit of the genus. A brief description of the incorrectly labelled specimen in the herbarium of Escuela Agricola Panamericana (EAP) at Zamorano near Tegucigalpa, Honduras, has been published. - WO

Five new tree species from Esmeralda, Ecuador, have now been described and illustrated. They are *Coussapoa rotunda* (Moraceae), *Magnolia striatifolia* (Magnoliaceae), *Matisia longipes* (Bombacaceae), *Rudgea jativae* (Rubiaceae), and *Sickingia standleyi* (Rubiaceae). - WO

A preliminary card key for families of Mexican trees has been prepared, with two tables for key construction. One hundred and nineteen families based upon Standley's Flora can be keyed. Readers can construct their own key by using hand-sorted punched cards with holes or perforations on the margin. - WO

B. Inherent Variation

Selection and inbreeding have often been suggested as a procedure for producing improved pines. Results from a trial inbreeding program in slash pine raise serious doubts as to its practicality. Seed yields from self-pollinations were 85 percent less than from wind pollinations on the same trees. Eighty percent of the trees produced only one selfed seedling per flower pollinated. After one growing season in the nursery, selfed seedlings were 24 percent smaller than wind pollinated seedlings from the same seed parents. These findings indicate that a relatively high degree of self-incompatibility and subsequent inbreeding depression limit the possibility of developing inbred lines of slash pine. - SO

Selfing in loblolly pine, as compared to outcrossing, results in a severe reduction in sound seed yield, and moderate decreases in filled seed germination, early survival, and early height growth. The low filled seed yield following selfing in loblolly pine limits the potential usefulness of an inbreeding program for this species. The extent of natural self-fertilization in loblolly was much higher in the lower crown (33 percent) than in the upper (7 percent). This phenomenon can cause a serious bias when using open-pollinated seeds for progeny tests and other genetic studies. About one-fourth of the selfed families contain mutant seedlings, of which there were 22 different forms. These mutants can be used as genetic markers in loblolly breeding programs; some mutants may be potentially desirable ornamentals. - SE

In natural populations of Douglas-fir self-pollination decreased seed yields by 87 percent. Controlled pollinations were made in five stands along an east-west transect through western Oregon. There was no significant difference between stands in self-fertility. - PNW

Breeding programs for eastern cottonwood will result in significant genetic gains. A clonal test of 98 selections of eastern cottonwood, a major timber species in the Mississippi Valley, resulted in simple heritability estimates for height (.47), diameter (.28), volume (.29), specific gravity (.36) and fiber length (.36). Melampsora rust resistance is strongly heritable (.89), so that rust resistance in cottonwood should be relatively easy to achieve in the lower Mississippi Valley. Site had no effect on wood properties, but did influence population responses in growth and Melampsora rust infection. There was no evidence of clone-site interactions for any character. Phenotypic and genetic correlations between characters were low (except height and diameter) and should not, therefore, influence selection procedures. - SO

Recent results from a hybrid poplar study indicate that increased growth rate does not adversely affect paper quality. In fact, the faster growing clones provide the best paper quality and the forest manager is advised to grow selected poplar clones at a maximum rate. Results of tests suggest that a poplar rotation for pulpwood in the Northeast can be reduced to 8 to 15 years by using improved material and maintaining optimum growth conditions. - NE

Initial root development of eastern cottonwood clones was influenced by the physiological condition of the source of the cuttings. Initial root development was under moderate genetic control, but was not related to early height growth. - SO

An investigation of growth responses of 16 families of Douglas-fir seedlings showed that some families respond better than others to increasing levels of fertilization. The technique employed in this study is useful for rapidly screening Douglas-fir selections for use on improved planting sites.-PNW

Nursery selection can be a very effective method of obtaining superior trees. Nursery selected loblolly pine seedlings averaged 47 feet in height after 10 years in one replication, or 9 feet taller than average seedlings. These selected seedlings exceed the limits of current site-index tables. - SE

An examination of 1300 planted longleaf pines after 30 years showed that selections made at age 3 for brown spot resistance and early resumption of height growth were twice as heavily infected with fusiform rust as trees not selected. These results indicate that great care must be exercised in the development of longleaf breeding programs for locations where fusiform rust is likely to be a serious problem. - SO

Foresters in the Lake States are advised to use white pine seed from stands no more than 100 miles from the planting site. A recent evaluation of 5-year-old white pine seed-source plantings in Minnesota, Wisconsin, and Michigan indicates that seed sources growing best in one location are not necessarily fast-growing in others. In the severe climate of Minnesota, Wisconsin, and upper Michigan, white pine seed should be obtained from areas where the mean January temperature is less than 20°F. For plantings in southern and western Michigan seed sources from mild Appalachian climates show promise, but require further testing. - NC

White spruce seedlings from the southeastern portion of the range are well adapted to all test sites, and some of them consistently exceed the averages of the plantations in height. Seed sources were field-tested for 5 years in 15 locations in a region extending from 42°-48°N. latitude from New Brunswick to North Dakota. White spruce seed from southeastern Ontario and adjacent Quebec may yield immediate improvement; selection in these regions should provide good, well-adapted genotypes. - NC

A study of natural variation in eastern cottonwood in the lower Mississippi Valley showed that fiber length ranged from 1.24 to 1.72 mm. at age 28 to 30. Fiber length increased from age 8 to 20 and then tended to level off. An analysis of the pattern of fiber length variation showed that maximum variation existed between individual trees and not between transects in locations.

These findings suggest that the breeder can effectively raise or lower the population average for fiber length in eastern cottonwood. - SO

Reciprocal seed-source plantings of longleaf pine between south coastal Mississippi and the mountains of northern Alabama have now refuted the long-held belief that the Alabama strain starts height growth more promptly. Each strain grew better in its own habitat. Earlier inception of height growth in northern Alabama apparently is due to low levels of brown spot disease in this area. - SO

In Louisiana an analysis of a 10-year-old seed-source plantation of longleaf pine showed that South Carolina, Georgia, and Texas sources were adapted, but that coastal Alabama and Mississippi seed sources were optimum choices for central Louisiana. Survival was positively correlated with mean annual temperature at the source; growth, however, was correlated with winter rainfall which was greater for the coastal seed sources. - SO

Sweetgum seed stratification requirements for optimum germination vary with the geographic origin of the seed. Seed from three sweetgum stands along each of six transects of latitude were stratified for varying periods of 0 to 64 days. Seed from northern sources required more stratification than seed from southern sources. Analysis disclosed that an increase of 10 days of 32^{o}F. temperature or less at the seed source was associated with an additional 1 1/2 days stratification to attain 90 percent total germination. In critical studies of seed germination it is essential to take provenance into consideration. - SO

Germination percent and rate were greater for sycamore seed from southern than from northern provenances. Stratification is not required for southern Georgia and north Florida sources. The critical length of stratification for all sources was 2 weeks. Longer stratification reduced germination at lower germination temperatures; higher germination temperatures tended to compensate for stratification requirements. - SE

DNA is the basic genetic material in living organisms. An analysis of 17 white spruce seed sources showed that, on the basis of nuclear DNA content, there were two populations, an eastern and a western one. In both populations DNA content varied with latitude of origin. The DNA content of white spruce was positively correlated with nuclear volume. The variation pattern of histone was similar to DNA. Eastern and western population differences in 2-year height growth of seedlings were also shown. In western, but not eastern, sources height growth varied inversely with DNA content. - NC

Variation in yellow birch flower and fruit characteristics differed between stands, but there was more variation within than between stands. Material from 53 collection points covering the range of the species was studied. Taxonomic studies of variation such as this are necessary to identify strains of trees useful in tree improvement programs. - NC

Mexican populations of sweetgum were uniformly less sensitive to short daylengths and cold temperatures than United States populations, according to a study at the University of Texas. Sweetgum seed sources from the entire species range including the disjunct Mexican populations were grown under controlled conditions at Austin, Texas, in 1966, 1967, and 1968. Seed-source differences were observed in bud break, stem elongation, fall coloration, and defoliation dates. Frost resistance was correlated with seed origin and with bark protein stability. Northern seed sources germinated more slowly over a range of germinating temperatures than southern sources. Mexican seed lots did not require stratification and were not sensitive to photoperiod. Mexican sources had long fiber tracheids, whereas northern U.S. populations had short fiber tracheids. Specific gravity was correlated with seed-source latitude. - WO

A P.L. 480 project in India examined for the first time the chromosomes of a large number of tree species. This survey substantially enlarges our knowledge of the cytology of temperate and subtropical woody plants, including a number of genera which are also represented in North America. It provides a valuable basis for the utilization of the Himalayan tree species as sources of germ plasm for the improvement of their North American relatives. - WO

A P.L. 480 project showed that the northern and southern populations of Norway spruce (Picea abies) in Poland are different in a number of morphological characteristics, although it is not possible to distinguish between the two on the basis of any single character. This information will be of direct benefit in choosing sources of seed for planting in the U.S. Also, the range of variation indicates that there are opportunities for improvement of selected traits through breeding. - WO

A second Polish P.L. 480 project revealed distinct differences in nutrient content and growth among Norway spruce seedlings from different seed origins. Among the provenances from southern Poland the original elevation is correlated positively with the concentration of nitrogen in the seedlings, and inversely with seedling height and dry weight. - WO

C. Hybridization

The four major southern pines can be artificially crossed with each other, but not with equal ease. Shortleaf, loblolly, and slash intercross readily, but longleaf is difficult to cross with shortleaf and loblolly. - SO

In south Mississippi three southern pine interspecific hybrids, longleaf x slash, shortleaf x slash, and shortleaf x loblolly, were equal or superior to check species with respect to survival, fusiform rust resistance, and growth. Maximum improvement in height and fusiform rust resistance can be achieved by selection within the parent species prior to making the hybrid cross. - SO

The knobcone x Monterey pine hybrid has potential value for esthetic revegetation of marginal sites and as a short rotation wood product on a range of sites in California. On three marginal sites in northern California, hybrid survival at the end of the third growing season was 77 to 98 percent and height averaged 3 feet, which is good for difficult sites. The hybrids are decisively superior to knobcone pine and perform as well or better than frost-susceptible Monterey pine. The hybrids may be particularly useful as an initial cover crop in brush conversion programs, since their rapid juvenile growth keeps them ahead of brush competition. - PSW

Erambert's hybrid, a putative southern pine hybrid, does not include slash pine in its parentage as was once thought. A graphic analysis of progeny from Erambert's hybrid, longleaf pine, longleaf-loblolly pine hybrid, and slash pine showed that Erambert's hybrid is most probably a longleaf-loblolly hybrid and is not related to slash pine. - SO

D. Methods Used in Tree Breeding

Nuclear volume and DNA content per meristematic cell are inversely correlated with radiosensitivity in higher plants, but when nine gymnosperm species were examined no relation was found between radiosensitivity and either DNA content or nuclear volume per cell. The expected relationship was observed when the radiation responses of gymnosperm and angiosperm seeds were considered together. More precise radiosensitivity prediction methods for gymnosperm seed must be devised. - NC

The parameters of the function $Y(u)=a+bu^c$, which has been used to estimate genetic parameters in forestry without raising progeny, can be estimated by a least squares iterative procedure. The method required an iterative series of linear approximations to the least squares estimates. Necessary tables have been compiled. - SO

A portable hydraulic-powered increment borer has been developed. It can also be adapted for use as an early auger or to bore holes in construction timbers at remote sites. This time- and labor-saving machine should find considerable application in many forestry research activities, particularly the genetic evaluation of wood properties of large standing trees. - PSW

A new multiple-dye stain, Brook Cyte-Chrome I, used in medical cytology greatly reduces the number of steps and the time required for staining microscope slides of plant material used in genetic studies. Routine embedding and chemical fixing procedures for plant material are employed in conjunction with the stain. - PSW

Root formation in sugar maple cuttings is related to the date of cutting. Rooting of cuttings increased from 0 for February, March, and April cuttings to 47.8 percent for those taken in early June. July cuttings did not root well (4.3 percent). Very substantial savings can be made by collecting cuttings at the proper time. - NE

A technique has been developed for control pollinating eastern cottonwood which is particularly useful in the early phases of a breeding program. Scions bearing female flower buds are bottle-grafted to potted stocks in mid-fall. After winter chilling, flower buds are forced and control pollinated. All the work with the exception of scion collections is done in the greenhouse. - SO

In sugar maple the male and female flowers do not develop synchronously. Two situations occur which vary from tree to tree. Male flowers develop in advance of female and vice-versa. Sychronization of blooming periods of both sexes in different trees can result in reciprocal pollination between trees. Time of flowering, especially in monoecious species such as sugar maple, has an important bearing on the development of effective pollination schedules in tree breeding programs. - NC

One to three-year-old western white pine pollen gave 52 to 110 percent of the seed yield of fresh pollens; there was evidence that 4- and 5-year-old pollens were also satisfactory. Western white pine seed set from 55 controlled crosses made with 1- to 5-year-old deep-freeze-stored pollen was compared with seed set from crosses made with fresh pollen from the same seed parents in the same pollinating seasons. It was concluded that it was safe to use deep-freeze-stored pollen when fresh pollen is not available. - INT

A study of floral receptivity in Douglas-fir disclosed that conelets could be pollinated over a surprisingly long period of time--up to 16 days--with some seed set after 20 days from the flower-swelling stage. This long range of time will prove advantageous in the conduct of Douglas-fir tree breeding programs. - PNW

Cold water spray reduced contamination of Douglas-fir seed orchard trees to acceptable levels, primarily by arresting development of floral buds during the period of natural Douglas-fir pollen release. This technique will aid seed-orchard management where pollen contamination is a problem. - PNW

Carefully controlled greenhouse tests of Douglas-fir resulted in a technique for maximizing seedling growth. Optimum growth conditions resulted in Douglas-fir seedlings 6 to 8 feet tall 2 years from seed. The technique is potentially useful for rapid progeny testing of Douglas-fir. - PNW

The Douglas-fir graft incompatibility screening technique makes possible analysis of cost alternatives for maximizing seed orchard establishment and minimizing the associated cost. Total costs per clone were estimated for grafting with and without screening for graft incompatibility. The most satisfactory method was to test each scion-stock combination for graft-incompatibility. Orchard establishment procedures can now be developed based on orchard design and the level of graft incompatibility that can be economically tolerated in the orchard. - PNW

Identical longleaf pine seedlings can be produced by splitting embryos in half when the seeds are germinating. This procedure is superior to air layering or to rooting of cuttings, which often result in seedlings of varying size and growth potential. Pairs of seedlings produced by the above procedure can be split again when they are 1 year old to produce four uniformly sized seedlings from a single embryo. - SO

A grafting procedure for longleaf pine resulting in approximately 40 percent graft success has been developed. Longleaf root stocks must develop at least a 6-inch terminal shoot to be successfully grafted. They can achieve the necessary height after 2 years in the nursery bed through proper care. Cleft grafting may be done successfully in the nursery, field, or on lifted potted stock. - SO

Latitudinal variation in cotyleton number and seed weight from a single year's collection of noble and California red firs can be used to identify the origin of seed lots. Seed lot testing and analysis will be helpful in reducing the serious consequences resulting from the use of unidentified off-site seed and seedlings in nobel and Claifornia red fir reforestation programs. - PNW

Populus nigra stem segments require three or more days in darkness to root, according to a P.L. 480 study in India. The number of roots increases with the number of dark days. The auxins IAA and IBA eliminate the dark requirement. Gibberellic acid (GA_3) inhibits root formation under favorable light conditions, and sucrose in conjunction with auxins stimulates rooting. - WO

Biochemical research under a P. L. 480 project in Korea revealed that a high carbon/nitrogen ratio due to a low level of nitrogen, a low amino acid content, and ability to manufacture growth promoting substances early in the growing season were characteristics of easy-to-root trees. - WO

A study supported by P. L. 480 funds in Finland produced an important paper on conifer pollen dispersal that will be helpful in seed orchard management. It showed that in a forested country like Finland pollen is dispersed very widely from its origin. Counts of pollen were also consistently found to be just as high or higher at 300 meters above the stands as in the stands themselves. A theoretical model of pollen dispersal from natural stands was proposed on the basis of this study. - WO

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TIMBER-RELATED CROPS AND ENVIRONMENTAL IMPROVEMENT RESEARCH

Problems and Objectives

The forests of the United States produce a number of timber-related forest crops, some of which are sources of important industries. These products include naval stores, maple sap, Christmas trees, and a group of minor crops composed of edible, medicinal, and decorative materials. Some of these crops, independently or in combination with timber production, greatly enhance the total income of forest owners. These crops also provide a ready cash income to individuals in many low-income areas. Other timber-related projects in this program concern the establishment and maintenance of shelterbelts on the Great Plains, and the development of special-purpose tree plantings and other forestry practices to improve the quality and appearance of rural and urban environments. The demands are great for knowledge on how to grow and maintain trees in areas being engulfed by today's urban sprawl. Trees are an important aspect of recreation and beauty in our modern environment.

Major objectives of the research are:

1. To determine the potential of timber-related crops to contribute to rural economies.
2. To develop efficient methods of producing gum naval stores, maple sap, Christmas trees, and medicinal and decorative plants.
3. To develop improved trees for planting on the Great Plains to reduce wind erosion, protect crops, ameliorate the environment, and provide natural beauty.
4. To develop methods to establish and maintain shelterbelts and other plantings of trees to improve the environment.
5. To develop cultural techniques to establish and grow trees in urban and suburban environments, with emphasis on establishment methods, plant materials, and maintenance of tree vigor.

A. Naval Stores

A strain of slash pine developed for gum production produced an average of 487 barrels pine gum per crop for 4 consecutive years, almost double the average crop. Production was determined by employing commercial chipping methods. It is expected that gum yields from "high-gum" seed orchards which have been established by further selection will surpass the superior gum yields already achieved through breeding. - SE

A mechanical system for harvesting pine gum has been devised which will enable woods laborers to produce 4 times as much pine gum as with present techniques and equipment. Moreover, the gum will be more easily processed, of better quality, and of higher value. The system involves a new method of applying sulfuric acid to the faces, a cheap, efficient, disposable gum cup, mechanical cup application, a new chipping tool, and a woods prime mover for collecting and transporting gum. - SE

Wounding trees changes the terpene composition of slash pine gum in the wound area. This phenomenon could have a bearing upon the individual tree's susceptibility to insect attack. An analysis of wound effects on variation in terpene composition should prove useful in elucidating the details of terpene biosynthesis. - SE

By the development of a simple miniature chipping technique, and a method for optimizing growth, slash pine progenies can now be evaluated for gum yield at 2.5 instead of 8 to 10 years. The gum yield of seedling families was strongly correlated with that of commercially chipped parents. Microchipping, in addition to reducing progeny test time, can serve as a selection tool for rapidly determining the value of candidate trees for gum yield. - SE

A P.L. 480 project in Israel is studying the morphological and anatomical changes related to resin stimulation in *Pinus halepensis*. Preliminary results suggest that resin acids are synthesized in spherosomes in duct cells and in other parenchymatous cells in young tissues. - WO

B. Maple Sap Production

The magnitude of variation in sap yield between sugar maple trees precludes simple random sampling in research. The use of paired tap holes on the same tree, and tree-pairing on the basis of previous yield, effectively overcomes the effect of between-tree variation. These considerations should improve the efficiency of sap production research. - NE

A practical method for the determination of maple sap sweetness permits rapid evaluation of the breeding value of sugar maple selections. A microtapping technique has been designed for 2-year-old potted seedlings maintained under carefully controlled greenhouse conditions. Sugar percentages are read in a small portable hand-held refractometer. - NE

The application of vacuum to tap holes has been shown to improve maple sap yields by as much as 300 percent. Vacuum pumping is particularly advantageous on level sites. Research on movement of dyed sap and dissipation of tree pressure showed that tap-hole yields from multi-tapped trees were independent, so that increased vacuum tap yields are net increased yields per tree. - NE

It is not profitable to tap the same tree in the fall and in the spring. Spring-tapped sugar maple trees yielded more sap than trees tapped both in fall and spring. Moreover, the sugar concentration of fall sap was markedly lower than that of spring sap. But fall sugar percentages can be used as reliable indicators of sugar-bush production potentials and as guides to thinning. Removing trees with low sap sugar may improve stand sugar percents by as much as one-half. - NE

Selected sugar maple trees show a superiority of approximately 50 percent in sap sweetness compared to average trees. Over 21,000 trees were examined and 27 have been selected for the tree improvement program. The sweetest tree in the tree improvement program has sap with 10.8 percent sugar content, five times greater than average production trees. - NE

C. Shelterbelts

Sprinkler irrigation is a new concept--in which shelterbelts play a key role--for the management of north-central Nebraska agricultural resources. Cattle are confined to feet lots during the summer, while cornis grown on irrigated circular quarter-section sized areas, and then grazed on corn stubble during the winter months. Circular belts of trees around the irrigated area provide crop protection and aid in uniform water distribution. The non-irrigated triangular areas in the corners are surrounded by trees which protect cattle during severe winter weather. Sound recommendations are available for design and species composition for these new-design shelterbelts. Such shelterbelts can be used for Christmas tree production without adversely affecting their protection function. - RM

Release improved the growth and crown form of five shelterbelt species. Green ash, hackberry, honeylocust, Siberian, and American elms were released from crowding by cutting adjacent trees in 20-year-old, 10-row shelterbelts. New epicormic branches on the lower stems of released trees, and stump sprouts from cut trees, helped restore windbreak density and restricted invasion of grass and weeds. - RM

E. Other

Research has been initiated on seed germination and cultural conditions required for the successful propagation of Lobelia inflata (Indian tobacco) and other native medicinal plants. Lobeline sulfate, one of the alkaloid constituents of L. inflata, is a commercially important drug for the treatment of respiratory diseases and as an aid in curtailing smoking. Collection of *L. inflata* and other Appalachian medicinal herbs used to be an important source of supplemental income for residents of Appalachia. But it has decreased sharply in recent years for a number of reasons, including a marked reduction in natural plant populations. - *NE*

One Appalachian plant with an increasing harvest is deerstongue (*Trilisa odoratissima*). This herb is an excellent source of coumarin which gives tobacco a sweet taste. - *NC*

Potential cull Christmas trees can be saved by straightening them. Young, partially frost-heaved Christmas trees develop a basal crook when they resume growth, and are subsequently culled. These trees can be saved by straightening leaning trees in the spring before growth commences. - *NE*

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WATERSHED, RECREATION, AND RANGE RESEARCH

FOREST SOIL AND WATER RESEARCH

Problems and Objectives

Present water demand for agricultural, industrial, and municipal uses is estimated to be about 270 billion gallons of fresh water per day. Although much of this water is returned to streamflow, shortages already exist. Considering fresh water only, future demands call for almost 400 b.g.d. by 1980 and almost 600 b.g.d. by the year 2000. The most logical place to look for additional supplies of high-quality water is in river headwaters which are in forests, associated rangelands, or alpine regions. Forest Service research has produced scientific evidence that streamflow can be substantially increased by a variety of vegetative management techniques. At the same time, these watershed lands must be managed carefully to repair damage from past mismanagement and to prevent any future damage to rural lands.

The aims of forest soil and water research are to devise methods for:

1. Improving water yields for agriculture, industry, and municipal use.
2. Preventing watershed damage by timber harvesting, logging road construction, and grazing.
3. Reducing flood damages.
4. Restoring natural beauty and soil stability in watersheds damaged by farming, grazing, mining, and fire.
5. Improving productivity of wetland and upland forest soils.
6. Preventing pollution of soil and water.

Progress

A. Improvement of Water Supplies for Agriculture, Industries, and Municipalities by Watershed Management

1. Snowpack control yields water bonus. Soil freezing in the White Mountains of Arizona has a significant effect on the disposition of snowmelt water. Concrete frost occurs in the open grasslands and has increased the overland flow of water. Only granular frost is formed in the timber types and it appears to increase the permeability of soil resulting in less overland flow and greater downward movement. Here is an opportunity for the land manager to have some control over water movement by manipulation of the vegetative cover. - RM

Observations were made in Arizona of snow accumulation and melt under several densities and demonstration cuttings of ponderosa pine. Accumulation was increased by a clearcut block on a north aspect, on a west aspect strip 3/4 as wide as tree height, and on east aspect strips of widths 1 1/2 that of tree height. The east aspect strips and the low density stands each increased snowmelt. Snow accumulation was not affected by strips cut on south or southwest aspects or by different pine stocking levels. - RM

Measurements of incident and reflected shortwave radiation from snow lodged on the crowns of a red pine plantation in upstate New York showed a reflectance at midday of 20 percent of the incoming radiation. Energy available for evaporation of intercepted snow thus may be four times greater than for fresh snowpack on the ground, the latter having an observed reflectance ranging from 60 to 85 percent. - NE

2. More water by manipulating vegetation. Water yield increased after cutting ponderosa pine on a mountain watershed in eastern Arizona. During the first complete water year following treatment, streamflow totaled over 1 inch more than would have occurred without treatment. The treatment in this case was a clearcut of only one-sixth of the watershed and the improvement cutting of the timber stand on the remaining area. The objective here was to develop a system of management to improve both the water and timber yields. - RM

A 28-inch sugar pine tree in the north central Sierra Nevada of California used over 23,000 gallons of water during the 1966 summer period. This amount was additional water--over and above that attributed to simple evaporation from the soil surface--extracted from a plot with a radius of 41.15 feet. - PSW

Water yields may drop sharply as a result of vegetation fertilization. Although information is limited so far, research at the Coweeta Hydrologic Laboratory in western North Carolina showed that water yield was lowered by fertilizing a grass-covered watershed. However, other work in Florida, Georgia, and North Carolina shows the beneficial effects of fertilization on the increased yield and quality of cattle forage and wildlife plants. - SE

An isotope inserted in the sap stream of coniferous trees in the high Sierras made it possible to measure the rate of water movement. After small lateral roots were immersed, in situ, into vials of phosphorus-32 solution, the upward movement was monitored with a portable scintillation detector. This is a first step in developing a method of estimating water use by a tree. - PSW

B. Protection and Wise Stewardship of Forest Soil and Water Resources

Forest soils in eastern Washington were found to be much more erodible than similar soils in western Washington, which has a more humid climate. The difference, up to 45 percent, was attributed to the influence of climate on the production of plant litter and its subsequent decomposition and mixing with mineral soil. - PNW

A loss of about 710 pounds per acre per year of till soil and bedrock by chemical weathering is proceeding in an undisturbed ecosystem at the Hubbard Brook Experimental Forest in New Hampshire. This information should permit accurate appraisals of possible changes in weathering rates induced by vegetative manipulations of the forest. - NE

Russianthistle is detrimental to desirable perennial grasses on semidesert rangelands in New Mexico. A common annual plant that establishes itself quickly after watershed treatment, it is a vigorous competitor for limited soil moisture. Wherever Russianthistle has become established and remained on the area over winter, the desirable plants such as alkali sacaton have declined. However, it has also been found that where the dead Russianthistle plants were removed for 1 year, the ground cover returned to its original level. - RM

C. Reduction of Human and Economic Loss from Floods

A chaparral-covered watershed in central Arizona stored approximately 20 inches of water during an extremely high rainfall period in 1965. Rainfall amounted to more than 24 inches and only 2.4 inches ran off in streamflow. The soil and underlying fractured rock are deep and porous, affording an exceptional storage reservoir. Here is another opportunity for the watershed manager to control water movements. If flooding is a problem, the watershed should be left in chaparral rather than converting it to some high water yielding vegetation. - RM

A study of 65 white pine stands in Massachusetts revealed that storage by the forest floor would have little effect on the volume of flood runoff during the growing season and an even smaller effect during the dormant season when humus is normally wet. The principal hydrologic function of the forest floor is to protect the soil surface and permit ready entry of rainfall into the soil. - NE

Spring flood flows in northern Idaho are not necessarily associated with rain-on-snow. At two small watersheds, rain-on-snow meteorological events were related to slightly more than half the spring peak flows; but on another watershed, three-fourths of the spring floods were associated with snowmelt alone. Short term high temperature periods are very important in triggering spring floods from melting snow. INT

D. Restoration of Soil Stability, Natural Beauty, and Income Opportunity

1. Abandoned farmlands restored by forest growth. Low turbidity, close to that found in forest streams, occurred in two gaged watersheds on abandoned farms near Parsons, West Virginia, despite evidence of severe erosion when farming was practiced. Apparently, natural revegetation is providing adequate protection on much of West Virginia's abandoned farmland which comprises about 9 percent of West Virginia, according to the 1959 U.S. Census of Agriculture. Gaging of the watersheds began in 1957, and to date there is no evidence that the volunteer afforestation is decreasing streamflow. - NE

Fertilization experiments are being conducted at the Forest Hydrology Laboratory in Oxford, Mississippi, in an effort to reduce the time required for a protective layer of litter to be formed on the soil surface. During the first year of the study, the weight of foliage produced by pot grown loblolly pine seedlings was doubled by applying large amounts of nitrogen and phosphorus fertilizer. A given amount of fertilizer was more effective in 10 small doses than in 1 large one. - SO

A half-million acres of loblolly pine plantations are restoring the natural hydrologic functions of the Yazoo-Little Tallahatchie watershed in north Mississippi. The plantations are reducing sediment production and restoring the ability of permeable outcrops to accept and store rainfall. Where well-drained soils overlie permeable strata, the entire annual rainfall can enter the soil and rock rather than run off as stormflow. - SO

2. Engineering new watercourses. Badly eroding gullies have been converted to vegetated waterways on mountain slopes in Colorado. Three years after the conversion, they had lost only 9 percent as much soil as comparable untreated gullies. This is still an experimental procedure, perhaps not applicable to all sites, but will be given further study. - RM

Two contrasting engineering approaches to erosion control have been recommended for mountain slopes in Colorado. The first approach resists natural erosive forces by such measures as grassed waterways and check dams. The second utilizes natural forces as in Italian hydraulic reclamation where slopes are smoothed to provide a more erosion-resistant topography. The objective of both approaches is to establish a cover of vegetation. - RM

3. Quick grass cover on spoil banks. Survival of sycamore, sweetgum, white pine and loblolly pine seedlings was not significantly affected by a prior established fescue ground cover on coal mine spoil banks in eastern Kentucky. Tree growth was reduced due to competition, however. - NE

In Kentucky, weeping lovegrass provided faster initial cover on extremely acid strip mine spoils than any other perennial grass or legumes tested. It also proved better adapted to drier sites and summer growing conditions than most cool-season grasses. - NE

Applications of lime were essential to establishment of crown vetch on coal breaker refuse in the Pennsylvania Anthracite Region, and mulch treatments were highly beneficial. Fertilizer applications had only slight effect on either establishment or growth. NE

4. Stabilizing mine access roads. Compression tests on three eastern Kentucky soils blended with salts, lime, and several petroleum and tar compounds revealed asphalt, sealing oil, and mixing oil as the best of the additives for stabilizing mine access roads. Load bearing strength of the asphalt and oil treated soils was much improved and roads thus treated should be more suitable for all-weather haulage with a minimum of sediment movement into streams. - NE

5. Ski slopes require attention, too. A starter fertilizer to establish ground cover appears to be necessary in ski slope stabilization near Wenatchee, Washington. Crested wheatgrass, tested both in the laboratory and in field plots on the newly developed ski slopes, did not develop without fertilization. - PNW

E. Improvement of the Productivity of Wetland and Upland Forest Soils

Many perennial streams in the mountains of Wyoming and other Rocky Mountain States have their sources in bogs. In general, these bogs are much smaller than the large filled-lake bogs in the Lake States. Nevertheless, they are composed of organic fill and the peats exhibit qualities similar to those in the classical peat bogs. The upper layers are relatively new deposits that contain large voids and conduct water freely; while the lower layers are decomposed and compact peats that drain extremely slowly. - RM

Research has determined that the pronounced lean in pine trees planted in wet, sandy flatwoods of northwest Florida is caused by a combination of inadequately drained soil and improper machine planting. Under these conditions, the root systems do not provide sufficient support to withstand the strong winds that sweep over open sites. About 75 percent of the leaning trees eventually died. Indications are that much of the mortality can be eliminated by improved water control. - SE

F. Prevention of Soil and Water Pollution

Nitrogen brought down by rain does not constitute a significant addition to the forest ecosystem in Oregon coastal areas. Nitrogen, particularly in the nitrate and nitrite forms, is receiving much attention as a serious potential water pollutant. However, the Oregon study shows that rainfall contains only about 1.3 pounds of nitrogen per acre each year. Moreover, 87 percent of the total was in the organic form, which is not considered a pollutant. - PNW

Fall rains in coastal Oregon did not introduce herbicides into streams flowing through herbicide-treated forest areas. No measurable quantity (tests were sensitive to 1 part per billion) of amitrole or phenoxy (2,4-D and 2,4,5-T) herbicides were detected in water samples taken after fall rainstorms. It appears, therefore, that this period of potential contamination can be eliminated from consideration. PNW

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RANGE MANAGEMENT AND ECOLOGY RESEARCH

Problems and Objectives

Rangeland in the United States is a 900-million-acre resource which benefits a large segment of rural and urban America through production of forage for livestock and wildlife, attendant services and industries, husbandry of soil and water values, and human enjoyment of its aesthetic qualities. On extensive areas, however, many ranges are far below their productive potential and in the western mountains, especially, watershed values have been impaired by improper use. Management of these lands is often complicated by a delicate balance of climate, vegetation, soils, and topography. Furthermore, livestock grazing must be coordinated with other land uses. Consumer demands for a projected 2.8 additional tons of beef by 1980 will be satisfied in part by intensified application of past research with the findings of planned, new research.

Major objectives of research are to:

1. Identify, measure, and evaluate the forage resource efficiently.
2. Determine growth characteristics and requirements of the vegetation.
3. Develop optimum management systems for maximum production of forage and livestock.
4. Determine the effects of fire and other range improvement practices.
5. Determine the influence of rodents and other range pests to provide a basis for control.

Progress

A. Evaluating Range Resources

Forage managers in the Ozark region have needed a field book for identifying plants and describing their value for livestock and wildlife. A publication intended to fill that need has been issued as USDA Agriculture Handbook No. 356, entitled "Ozark range and wildlife plants." - NC

A comprehensive bibliography listing about 650 important publications relating to rangelands of the South has been published as "Selected bibliography on southern range management, 1962-1967," USDA Forest Service Research Paper SO-38. This paper updates an earlier bibliography on southern range management issued in 1962. - SO

The percentages of species making up 30 percent, or more, of a mixture of forage can be reliably determined using a microscopic point method. Examinations were made on masticated and partially digested forage removed via a rumen fistula in a steer. Prediction equations from known mixtures fed to the animal showed a 1:1 ratio of percent weight to percent points for grasses and a 2:1 ratio for half shrubs. - RM

The crude protein content of forage in steer rumen samples was much greater than the estimated protein content as determined by species composition in rumen samples and laboratory determinations of crude protein in hand-clipped samples. This appeared to be due largely to animal selectivity of specific plant parts and indicates the difficulty in estimating the protein content of the diet. - RM

For repeated measurements of herbage, boundaries of small contiguous plots can be marked with wires held taut by springs. In a trial on Louisiana range, this method was superior to delineating plots with frames. - SO

The ocular estimate by plot method of estimating herbage utilization may be biased by the lack of proper weighting procedures. The nature and magnitude of bias is related to sample size, the variability and distribution of yield, and correlation between herbage production and use by livestock. To form unbiased estimates of the population mean, individual estimates must be weighted by the mean of production. - RM

Large scale (70-mm.) color and color infrared aerial photographs were taken of northeastern California grasslands and shrublands to evaluate their possible use in range inventories. Because of the high resolution, and color dimensions of hue, value, and chroma, trained interpreters can use this large-scale photography for (1) Detecting and identifying range plants; (2) identifying soil surface features; and (3) quantifying plant and soil surface features. A photo key was developed using 1:920 scale infrared color photographs of a mountain grassland in Colorado. The most useful characteristics were: (1) General color, (2) pattern and texture, (3) relative size, and (4) specific color of the object. - RM

B. Characteristics and Requirements of Range Plants

Sulfur affected top growth more than root growth in Spanish clover and Italian ryegrass. The sulfate form of sulfur should be used to diagnose the sulfur status of both species. The critical level of sulfate sulfur is about 100 ppm., dry basis, in the middle stem section of the shoots of Spanish clover. In Italian ryegrass, 100 ppm. in recently matured leaf tissue is considered adequate. - PSW

Nitrate nitrogen in shoots of different strains of Idaho fescue can be used to diagnose nitrogen status at the late vegetative growth stage. As a general rule, nitrate nitrogen should be above 500 ppm., dry basis, for maximum yield. - PSW

Planting success with important browse species is enhanced with knowledge of their germination and seedling requirements. Germination conditions for fourwing saltbush are likely to be optimum during the cooler part of the year in the Southwest. The best germination occurs between temperatures of 55° and 75°F., but 90 percent germination occurred over a wide temperature range. Alternating temperatures generally induced less germination then constant temperatures. - RM

Soil drying may not be as detrimental to germination of winterfat seeds during cold weather. Germination decreased and was delayed as soil moisture stress increased, but the decreases were proportionately less at lower temperatures. One of two sources of seed germinated better under all moisture stresses, and further research may show that certain seed sources are superior for revegetation work. Special storage conditions are unnecessary for fourwing saltbush seeds. Viability of seeds stored under ordinary room conditions was still high after 6 years. - RM

A half-hour soak in 30 percent hydrogen peroxide, either alone or following 48 hours in water, increased and speeded germination of mountain mahogany and cliffrose seeds. The peroxide treatment reduced seedborne microflora but it also induced some abnormal seedling development. Weaker peroxide solutions, or shorter soaking times may stimulate germination without adversely affecting seedling development. - RM

Leacheate from Atriplex polycarpa seeds soaked in water for 48 hours severely limited the germination of other seeds of the same species. Temperature also had an important effect on germination. After 5 days the highest germination was from seeds stored at 20°C.; after 14 and 30 days a temperature treatment of 15°C. produced the best germination. - PSW

Extracts from leaves and nonwoody stems of many species contain materials that inhibit the growth of seedlings of other species or even of their own species. When grown in extracts from Utah Juniper, growth of squirreltail seedlings was almost completely inhibited and growth of blue grama seedlings was greatly reduced. Extracts from ponderosa pine had less effect. - RM

Seedling root development of saw palmetto is reduced by soil moisture saturation in the South, and these seedlings are also more vulnerable to competition and drought. Growth and development of seedlings is slow and establishment requires from 2 to 6 years. Maximum growth occurs in the summer rainy season, and 80 percent of the annual growth occurs between April and October. - SE

Daily minimum soil temperatures were lowest at the surface and increased with depth in a semidesert habitat in southern Arizona. Diurnal variation was as much as 75°F. at the surface and 1° or 2°F. at the 24-inch depth.

Soil temperatures at the 3-, 12-, and 24-inch depths ranged mostly between 40° and 60°F. during the winter months and between 70° and 90°F. during the summer months. Maximum and minimum temperatures recorded were 141° and 29°F. - RM

Earthen pellets containing seeds for rangeland seeding in Arizona, New Mexico, and Colorado were tested in the laboratory and greenhouse. Tests showed that pellets containing small seeds retained viability when properly handled; large seeds usually were damaged by the pelleting process. Field trials showed that seedling stands from pellet seedlings were more sparse than with methods usually used. - RM

C. Livestock Grazing Practices

In southern Idaho, yearling cattle made satisfactory weight gain on cheatgrass range under either rotational or continuous grazing systems. Weight gains were greatest in the late spring and lowest in the fall. Yearly variation in the production of both beef and forage was apparently due to weather conditions. Grazing capacity and beef production was highest under continuous heavy grazing, but this system cannot be recommended until its effect on vegetation and soil is known. - INT

During the summer, yearlings and calves gained as well on crested wheatgrass as on nearby mountain range. No additional gains were produced with supplemental rations. Cows showed the only significant response to protein supplement. They finished the season about 75 pounds heavier than nonsupplemented cows. Cows receiving supplements on crested wheatgrass range made gains that were comparable to nonsupplemented cows on summer mountain range. - INT

Spring deferment may be the key to improving extensive areas of semidesert range in the Southwest. On the Santa Rita Experimental Range in Arizona, perennial grass density doubled during a 4-year trial of summer deferment, winter deferment, and year-long grazing. Grass density tripled under spring deferment, however, indicating that grazing during the March-June period is more critical than summer or winter grazing. - RM

Spring grazing of crested wheatgrass should be managed under a rotation system that uses about 65 percent of the annual forage crop in west-central Utah. On the Benmore Experimental Range, big sagebrush and rubber rabbitbrush invaded crested wheatgrass under all grazing treatments but was greatest with heavy grazing. - INT

On alpine allotments in Wyoming, one band of Columbia sheep was unherded while a herder stayed with another band. Both bands behaved in much the same manner. The unherded sheep apparently were conditioned by herding during the other 10 months of the year. The unherded band remained in a single group or on rare occasions split into two or three groups for short periods. The unherded sheep grazed the allotment more uniformly than the herded sheep. Lambs gained equally well in both bands. - RM

D. Burning and Other Range Improvements

Cabling usually increases cholla cactus because the scattered stem joints and fruit become rooted and grow. However, recent results from the Santa Rita Experimental Range show that very few of these new plants survive more than a year or two if the parent cholla stand has already started to decline naturally. In such areas, cabling may be justified to open up the range and make it easier to find cattle, but cabling to control cactus is not justified. - RM

Herbicides, especially 2,4,5-T in water, are effective in the control of the endemic saw palmetto when applied in combination with burning or other defoliation treatments. Mechanical disturbances which cut the palmetto stem and dislodge the root kill a large percentage of stems and greatly reduce its cover. This interest stems from the increased demands for greater production from southeastern forest ranges. - SE

Fire is characteristically used in the piney woods of the Southeast to produce repetitive stands of native legumes, but the results are frequently erratic and unpredictable. Seed germination following simulated fire conditions shows that dry heat is ineffective in increasing germination whereas moist heat greatly increased germination. - SE

Fire alone is not a significant factor in limiting saw palmetto in the South. Fire stimulates frond growth during the winter when unburned plants are relatively dormant, and burned plants may regain 80 percent of their crown coverage the first year. However, burning does reduce flowering and fruiting. Flowering increases significantly after 5 years of fire protection, and substantial fruit crops are produced after 6 to 9 years of fire protection. - SE

E. Range Pest Influences and Control

In southwestern Colorado soils, pocket gophers keep the surface soil mixed on many rangelands. Soils inhabited by gophers tend to be deeper than uninhabited soils. Gophers tended to avoid rocks larger than 2.5 cm. in diameter. They also moved relatively fewer rocks to the surface when the soil was dry and when it contained only a few large rocks. Rocks from 0.6 cm. to 2.5 cm. in diameter were more abundant in mounds and casts than in undisturbed topsoil. - RM

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WILDLIFE HABITAT MANAGEMENT AND ECOLOGY RESEARCH

Problems and Objectives

Wildlife is an important national asset. In addition to public pursuit of wildlife and its economic value, game and nongame species are enjoyed as part of the national landscape. Impacts such as poor logging practices, wildfire, roadbuilding, strip mining, or overuse by livestock and big game cause frequent problems and challenge wildlife and fish habitat research. Knowledge of the food and cover requirements of each species is essential to maintain these populations of wildlife. Rare and endangered species must be protected and their habitat improved to insure their preservation for future generations of people. Better ways must also be developed for fitting the needs of wildlife into the multiple use scheme.

Forest wildlife and fish management requires investigation of the following:

1. Selection, genetic improvement, and methods of seeding or planting for both native and introduced food and cover plants.
2. Habitat rehabilitation through type conversion and coordinated management to harmonize wildlife production with other land uses.
3. Ecological and physiological requirements of food and cover plants.
4. Improving fish habitat and food supplies.

Progress

A. Improving Wildlife Habitat

An outstanding guide has been prepared by Forest Service and Utah game biologists for revegetating game ranges in the Western States. It is entitled "Restoring big game range in Utah" and has been issued as Utah State Division of Fish and Game Publication No. 68-3. Over 1,000 plants were tested, and results are given for more than 200 promising species. - INT

Fifteen shrubs have been evaluated as to method of establishment, growth, and survival on burned and unburned sites in the Black Hills. In general, seed germination was better on the unburned site but growth and survival were better on the burned site. On the unburned site, bitterbrush, caragana, silverberry, and American plum appeared best suited. Bitterbrush was best established by transplanting potted seedlings on both burned and unburned sites. Other species did best from nursery stock. On the burned site, silverberry transplants grew very well and sprouted profusely. Silver buffalo berry grew well after slow initial growth. - RM

In southern Idaho where moderate use on bitterbrush is the rule and where shrubs are exposed to heavy utilization only in the most severe winters, a revegetation program can succeed without drastic reductions in deer numbers. Survival of seeded bitterbrush was 20 percent greater and average crown area of protected shrubs was up to three times greater than browsed shrubs. Although young shrubs moderately browsed each winter for 15 years were smaller, browsing was not considered harmful. - INT

Several browse species in northern Idaho were treated with different herbicides to reduce crown height and make more forage available to deer and elk. Because of rapid regrowth, the height reductions of mountain maple and willow lasted less than 6 years. Redstem ceanothus, the most desirable browse plant tested, was killed by all spraying treatments. - INT

B. Integrating Wildlife and Other Land Uses

Timber harvesting of ponderosa pine forests of Arizona increased both deer and elk use up to 14 months after cutting. One-sixth of the area was clearcut in patches of 2 to 32 acres, and remaining stands were thinned to achieve optimum tree growth. The diverse habitat created by cutting provided more forage, but sufficient trees were left for cover. - RM

Thinning increases both seedlings and sprouts in mixed oak and cove hardwoods--both are important deer forage in West Virginia. Stands of high basal areas (100 $ft.^2$ per acre) produce mostly seedling browse in the mixed oak types, but basal areas of 65-75 $ft.^2$ per acre favor sprouting. In cove hardwoods, basal areas between 85 and 95 $ft.^2$ per acre stimulate both seedlings and sprouts. - NE

Major changes are taking place in southern forestry practices to meet national timber needs. These changes will be both good and bad for wildlife habitat. Trends working against wildlife habitat are reduced acreage of bottom land hardwood forests, removal of cull hardwoods from uplands, and intensive timber management practices such as control of understory vegetation, type conversion, and elimination of hardwoods. Wildlife habitat will be favored by practices such as prescribed burning, timber thinning, and wide spacing of trees. - SO

Deferred-rotation ranges were more attractive to deer than season-long ranges on the Starkey Experimental Forest and Range in northeastern Oregon, but elk showed no special preference. As cattle stocking increased, however, elk use decreased but deer use was not influenced. Deer also preferred forested areas over grassland openings, but elk did not favor either type. An exception was that elk preferred the forest on ranges where cattle did not graze. - PNW

C. Evaluating Wildlife Habitat

Browse yields on the Ouachita National Forest of Oklahoma ranged from 85 pounds per acre in undisturbed oak-pine timber types to 182 pounds per acre in oak-pine timber types disturbed by timber stand improvement and harvest cutting. Winter yields averaged 19 pounds per acre over the entire forest, and only 14 pounds of this was considered preferred deer food. Low yields of browse, especially evergreens for late winter forage, may be limiting white-tailed deer in this region. - SO

Sparsely timbered glades and bottom land hardwoods in an Arkansas Ozark forest produced the most herbage and evergreen browse. They also received the heaviest winter use when mast was scarce in other types. When mast was abundant deer ate little else and concentrated in the heavily wooded areas, particularly the upland hardwoods. When mast yields were low, use of herbaceous forage increased and forest type preferences changed. - SO

Rusty blackhaw, yaupon, greenbrier, and yellow jasmine are major deer food plants in southern upland pine-hardwood forests. The leaves of the evergreens, yaupon, and jasmine are especially valuable because of their relatively high protein content throughout the year and their availability as winter browse. None of the plants satisfied the minimum phosphorous requirement of deer. - SO

A useful key has been developed for identifying shrubby plants by microscopic examination of the xylem. It can be used to substantiate identifications made with ordinary keys and also aid identification when flowers, leaves, and fruits are not available. The publication's title is "Comparative wood anatomy of some shrubs native to the Northern Rocky Mountains," and it has been issued as USDA Forest Service Research Paper INT-45. - INT

A comprehensive review of 329 references summarizes much of the literature on the greater prairie chicken and the sharp-tailed grouse. It will enable careful planning of new research to yield needed information and yet not duplicate past studies. The publication entitled "Characteristics and habitat requirements of the greater prairie chicken and sharp-tailed grouse--a review of the literature" has been issued as USDA Conservation Research Report No. 12. - RM

Deer forage preferences are being studied with free-ranging tame deer on the Allegheny National Forest in Pennsylvania. Use of tame deer permits closeup observations of forage choices in relation to availability. This, in turn, permits better evaluation of habitat quality and more discriminating tests of nutritional values of forage plants. A major limitation in working with tame deer is the large investment in animal training, equipment, and manpower. - NE

The need to follow the movements of deer, elk, and turkeys in the Southwest prompted the development of a miniature radio receiver with an amplifier stage added to increase receiving distance. Weight of the transmitter and one battery is 2 ounces; maximum battery life is 45 days, and maximum receiving distance is 2½ miles. - RM

Food consumption and weight changes of white-tailed deer vary seasonally. Decrease in food consumption and winter weight losses seem to be associated with physiological changes that occur during the breeding season. Mature deer may require less food to maintain themselves than immature deer. - SO

Under good forage conditions the diet of antelope consists of green grass and forbs in early spring, succulent forbs during late spring and summer, forbs and browse in the fall, and browse during the winter. During a dry summer or fall, antelope are forced to take less succulent forb material and more browse. When succulent forage is available, antelope do not require drinking water. During a drought, however, an animal may drink almost a gallon a day. - INT

The use of fecal material in diet studies has a number of advantages: (1) Forage species can be identified without having to see the animal feed, (2) the animal does not have to be removed from the population, and (3) the material is easily collected and stored. Techniques have been developed for examining deer and elk feces, and identification aids using both microscopic slides and photomicrographs of cuticular material have been prepared for 69 common forage plants in eastern Oregon. - PNW

Before the track count census method can be relied upon for determining deer numbers, enough counts must be taken to compensate for day-to-day variability. Track counts are practical but time consuming. In Florida, under ideal conditions, one man can count twenty 1-mile track transects per day. - SE

In the Southeast, data on deer movement were gathered and analyzed to evaluate the possible effect of vegetation types, moon phases, and weather. White-tailed deer on the coastal plain are nonrandomly distributed but have a consistent pattern of movement through their habitat. Uniform weather conditions prevailed during the period data were gathered, and its relationship to deer movement was very weak. Deer activity was not associated with any particular moon phase. - SE

Visual estimation techniques or nonrandom sampling methods may be the best way to sample shrub density. Bitterbrush density in a known parameter population was estimated with 19 variations of quadrat and plotless sampling techniques. Many methods were inaccurate with any size of sample, and all required unreasonably large samples for acceptable precision. Several methods required more effort than counting all plants on 1- or 2-acre areas. - INT

First tests of an electronic herbage meter produced fast and accurate estimates of herbage weight in the dense, high-yielding annual-grass type in California. Later tests on bunchgrass and meadow types were less efficient. Some problems were caused by calibration, low herbage yields, short stands, and variation in water content and ambient temperature, but these were more than offset by yield estimates that were up to 50 times faster than clipping. - PSW

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FOREST RECREATION RESEARCH

Problems and Objectives

Despite rising costs and increasing national and international pressures upon the American people, outdoor recreation continues to boom throughout America, and no letup is in sight. Today, outdoor recreation is indeed a major industry, an industry that annually generates at least a $25 billion a year market for goods and services, and an industry that provides a major opportunity for aesthetic and economic enhancement of rural America. The task of forest recreation research is to identify recreation needs and future demands, and provide information which will guide investment, development and management of public and private forest lands for recreation and the enchancement of natural beauty.

Specifically, the research objectives are to (1) characterize recreation users and use on public and private forest lands in order to better evaluate recreation needs, trends, and future demand, (2) determine the criteria for profitable income-producing recreation enterprises and their job producing opportunities, (3) develop and test design concepts and principles to guide the use, management, and enhancement of forest landscapes, (4) provide criteria to select, develop, and maintain heavily used forest recreation sites, (5) help find the place of outdoor recreation as a benefit to society, and (6) provide a better factual basis for policy and management of wilderness and multipurpose forest lands through ecological, social, and economic studies.

Progress

Law and order--greater public cooperation needed

Like other heavily populated communities, campgrounds throughout the United States are experiencing serious problems of law and order. Theft, vandalism, rule violation, and even more serious crimes are all too common. A research team studying depreciative behavior in northwestern National Forests, National Parks, and State Parks is finding the problem is much more extensive because of indifference, and inconsiderate and irresponsible attitudes on the part of many visitors. The researchers point out the norm of non-involvement is self-defeating. Visitors must assume more responsibility for their own property, that of their neighbors, and public property. Likewise, administrators must recognize that our urban oriented population needs more education in the care and use of the natural environment, that camping and outdoor recreation is a social experience, and policies, rules, and training of managers must be given emphasis equal to that of preserving the environment. - PNW

Commercial campground owners should find their "heavy-half"

It is a well established marketing fact that most purchasing is done by a fraction of the total market. In a New England study, we find the same pattern in camping. Half the campers do three-fourths of the camping. "Heavy-half" campers camped a minimum of 21 days. They averaged 34 days--three times as much as the light-half, and spent three times as much money. Heavy-half campers have large investments in equipment. Campground owners are encouraged to (1) ask their campers how many days they camp each year and to send extra mailings to those who camp more than 20 days, (2) advertise through equipment dealers and at equipment shows, and (3) advertise in camping magazines which have a large portion of heavy campers among their subscribers (as determined by readership surveys). - NE

Family camping is inexpensive, and campers are willing to pay reasonable campsite fees

Money spent on camping fees represents about one-fifth of a family's total trip expenses ($103). Daily camping expenditures in New Hampshire, including food, spanned a wide range but averaged about $11 per family in 1967. Two-thirds of the campers said $3 was a reasonable daily charge for a campsite. Of the remainder 30 percent favored a $2 charge, only 3 percent wanted a $1 charge, and 2 percent were willing to go as high as $6 for daily campsite rentals. - NE

Ecological diary of the BWCA landscape

Today, virgin forests occupy about 40 percent of Minnesota's Boundary Waters Canoe Area. The balance has been logged, either in the early era (1895-1930) or under controlled timber harvests since about 1940. Natural disturbances such as windstorms, insect outbreaks, and particularly fire have been important and dramatic factors for natural ecosystems which we are now seeking to maintain. Eighty to 90 percent of the Area's 400,000 acres of virgin forests date from wildfires during the past 400 years. - NC

Inventorying wilderness plant communities

Preservation of wilderness necessitates a thorough ecological understanding of the lands concerned to maintain their primitive character and, in some cases, to provide guides for restoring disturbed areas to their natural condition. Such a study is underway in the northwoods forest types of the Boundary Waters Canoe Area. Nine plant communities have been described and their important plants have been listed. Some cover a wide range of communities; others are restricted. For example, if a wilderness visitor wishes to see Reindeer Moss, the most likely place to look would be a Lichen Community. - NC

Communicating ideas and perceptions in landscape management

We seldom all mean the same thing or see the same thing when discussing or observing the landscape. Recognizing that clear communication is a must when considering the relationships between resource management and the visual resource, means for recording and expressing the landscape were devised in a California study. To do so, the landscape was considered as a visual, physical entity and not as a state of mind or abstract emotional quality. Six factors of scenic analysis and observation are described, graphically presented, and discussed using a broad span of examples. Three of the factors--form, spatial definition, and light--man can do little to alter. However through manipulation of the other three--distance, observer position, and sequence--profound impacts upon the total visual resource are possible. - PSW

A formula for predicting natural landscape preferences

Why is one landscape preferred more than another? A technique to quantify variables in a natural landscape, using 8- by 10-inch photos of forests, mountains, meadows, and water in various combinations was tested on Adirondack campers--a group that spans a broad section of the northeastern recreation public. Preference was dependent upon six items which can be measured easily, such as perimeter of immediate vegetation, perimeter of distant vegetation, and area of any kind of water. - NE

A formula for evaluating campsite preferences

Nine out of 40 campsite characteristics stood out as important in an analysis of camper use preferences in 24 Adirondack campgrounds. Among the nine were: area of lake upon which a campground was located, area of other lakes accessible, land area of developed swimming beach, percent of campsites from which the lake is visible, average distance of campsites to edge of lake, population of permanent residents within a 25-mile radius, and total number of campsites. - NE

Now you can use computers to make visibility maps

For years map makers and foresters have been making overlay-visibility maps to delineate areas which can be seen from a fire lookout, a mountaintop, or a scenic highway. In the past these maps have been made the hard way--by hand drawing profiles from a contour map. Now we can do it with a computer program developed for the purpose by Forest Service scientists in California. Input consists of data on elevations, by coordinates, which can be obtained from maps or aerial photos. The computer produces an overlay that shows the areas visible from any observation point. - PSW

Pruning landscape trees--How to do it

To assist practitioners in landscape beautification, an excellent practitioner's manual on pruning landscape trees has been prepared in cooperation with the University of California. The manual, well illustrated, is a compendium of tried and true practices and procedures on shaping, influencing flowering, invigorating, protecting, and strengthening both young and mature trees. - PSW

Staking landscape trees--How and how not to do it

Breakage or severe deformation of the tops of young, planted trees which have been staked is often a serious problem. Observations in California led to testing a hypothesis that there is a critical height of staking where stress on the young tree trunk is at a maximum. An analysis proved that stresses indeed varied from ground level to the top of the tree, and that effective staking is accomplished not by increasing the staking height indefinitely (obviously, an impractical solution!), but by reducing the height of staking. Then, prune the top if the trunk is weak and the top is large. - PSW

Revegetating worn areas--A problem not yet licked

There is a real need for practical measures to improve the physical condition of many recreation sites which are characterized by compacted and eroding soils, dead and dying vegetation, and generally poor appearance. A study of seeding of grass accompanied by intensive cultural measures in Georgia and Tennessee was not successful. All planting was done in late September, after the heavy use season, to minimize trampling during the initial stages of growth. Treatments included plowing, cultivation, mulching, fertilizing, rolling, and watering. Excellent stands of grass were established, yet despite light recreation use the following year, the grass was almost entirely absent on all study areas, regardless of species or treatment. - SE

A technique for measuring recreation use in winter sports areas

An effective double-sampling technique for estimating winter recreation use has been developed at a large winter sports area in Utah. Reliable estimates of total use, use by activity, number of visits, average length of ski time, and skier characteristics were obtained at a cost of less than $350 annually. The technique, which is applicable to other winter sports areas, employs two separate, simple linear regression analyses based on two independent variables--vehicular traffic counts (vehicles) and ski equipment rentals (dollars). Systematic sample counts of the number of people associated with each major use provided the dependent variable. - SE

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FOREST FIRE AND ATMOSPHERIC SCIENCES RESEARCH

Problems and Objectives

Forest fires have a continuing impact on every major wild land resource in all parts of the Nation. Forest fires are becoming more costly. Public and private expenditures for fire control now exceed $300 million per year. Forest fire losses also continue to increase. The average loss per fire increased 250 percent between 1962 and 1966 despite a strenuous and costly effort to promptly rehabilitate burned-over areas in order to reduce damage. Population pressures are changing the nature and increasing the complexity of forest fire problems. Suburbs merge gradually into the wild lands so that fires today involve homes as well as trees, and the safety of people becomes a major complicating factor in tactical firefighting decisions. The opportunities for forest fire and atmospheric science research to make significant reductions in both forest fire costs and damages are greater than ever before. Recent advances in many scientific fields can be developed through this research program for specific application to forest fire problems.

Major objectives of forest fire and atmospheric sciences research are to:

1. Develop knowledge of atmospheric behavior as related to forests and forest fires and technology for the application of weather information to the protection of forest resources.

2. Develop knowledge, technology and systems for weather modification with the objective of reducing losses from lightning-caused forest fires and of protecting forests and related agricultural resources from damage by hail and other weather phenomena.

3. Develop methods of preventing fires with emphasis on situations causing the greatest costs and losses.

4. Develop effective and economical methods for reducing the hazards of dangerous forest, brush, and range fuels.

5. Develop new and more effective techniques for detecting and suppressing fires burning under a variety of fuel, weather and topographic situations.

6. Develop fire control systems for improved protection from fire in intermingled forest and urban areas.

7. Develop improved ability to predict fire potential and fire behavior with emphasis on early warning of incipient conflagration conditions.

Progress

A. Atmospheric Physics and Forest Fire Meteorology

Cloud seeding tames lightning. At the end of the third year of field trials, the evidence that cloud seeding can be effective in reducing lightning activity is overwhelming. The pooled results show a 54 percent reduction in the average number of lightning strokes from seeded storms as compared with storms not seeded. Even more important, cloud-to-ground lightning (the kind that starts fires) was reduced 67 percent by seeding. The technique is now ready for full-scale field testing. - INT

Weather types and rapid fire spread. A California study has shown the broad-scale synoptic weather types which produce conditions conducive to rapid fire spread. These conditions are varying combinations of strong winds, low relative humidities, high temperatures, and lack of rainfall. Weather types associated with high fire danger were identified and described in each of the 14 weather regions covering the 48 contiguous United States. How often and for how long each type occurred by months for each weather station in a network of 89 stations over a period of years was also determined. In most regions, this study discovered that high fire danger typically exists around the periphery of high pressure areas. This information will help predict the occurrence of critical fire-weather periods and estimate their severity on a nationwide basis. - PSW

Airborne lightning sensing system. Project Skyfire has successfully tested an airborne version of a sensing system to identify and measure cloud-to-ground and cloud-to-cloud lightning discharges. The system overcomes interference from aircraft generated electrical noises and yields data comparable to previously developed ground based systems. This research development has a high potential for operational use in fire control to identify lightning strike zones as well as use in recording essential data for lightning suppression research. - INT

Marine air penetration into southern California. Researchers collected quantitative data on the penetration of marine air into the Arroyo Seco watershed of southern California. This data shows that both the temperature and wind fields are strongly influenced by the complex topography of the area. As this watershed is representative of many such drainages in coastal mountain ranges in the West, the information will have widespread application to fire control operations. - PSW

Nighttime fire weather for prescribed burning. An analyses of 8½ years of weather data shows that nighttime prescribed burning is feasible in the lower piedmont of Georgia 8 months of the year. Twenty-four percent of the nights in Macon and 15 percent of the nights in Athens met required criteria with respect to wind velocity, relative humidity and duration of these elements. These criteria are not met during the months of June through September. These results will be helpful to the expanding use of prescribed fire in wild land management. - SE

Surface mountain winds blowing under light Santa Ana[1] conditions. Scientists at the Forest Fire Laboratory, Riverside, California, have conducted a streamline analysis of canyon winds under light Santa Ana conditions. Santa Ana winds are closely related to both the horizontal and vertical winds above the surface, and cross-sectional analyses have shown how rapid wind shifts occur, especially near the convergence zone of the downslope lee winds and the opposing upslope winds. These results provide fire control officers with a better understanding of these complex winds and correspondingly better firefighting tactics. In addition, mathematical models derived from the results will help fire-weather forecasters predict localized fire weather more objectively. - PSW

Surface network defines the distances penetrated by sea-breeze fronts on the East Coast. Project THEO defined the distances penetrated by East Coast sea-breeze fronts and the relationships between passage time and distance from the sea. Penetration ranged from just onshore to at least 50 miles. In some cases the front lay onshore during the night and moved inland in the daytime from the night position. As a result, weather stations 5 to 15 miles inland recorded more sea-breeze frontal passages than stations on the immediate coast. During the last spring season 36 sea-breeze fronts were observed. However, not all of these passed any one station in the network. Passages by localities ranged from a maximum of 31 in the 10-mile wide corridor 5 to 15 miles inland to only 5 at a station 50 miles inland. Times of frontal passage ranged widely through the day at all localities. As sea-breeze fronts have a significant effect on fire behavior, their identity and travel distance are important to fire control operations. - SE

Wildfires respond to frequent changes in wind direction. A case study of two wildfires in coastal North Carolina describes frequent changes in surface wind direction which impaired control operations. In one the changes were due to the oscillatory passage of a sea-breeze front. In the other they were due to the passage of a pressure-trough line, a sea-breeze front, and the partial passage, retreat, and final passage of a surface cold front. Case studies of this type better explain the reasons for unusual fire behavior. - SE

Local weather greatly influenced by temperature at the surface and aloft. Local weather characteristics during the extreme conditions of a summer heat wave are greatly influenced by both surface and upper air temperature patterns. Analysis of local potential temperature on a topographic base map and the atmospheric cross section above increased our knowledge of the effect of these vertical temperature patterns. This helps define air strata and temperature-related airflow in mountainous regions with detail not possible with the usual pressure analysis alone. - PSW

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[1] The Santa Ana is a dry northeast wind occurring periodically in southern California that causes exceptionally high fire hazard.

B. Fire Physics and Chemistry

1. Fire Physics

The primary emphasis of the fire physics program during 1968 was to develop mathematical models of fire behavior characteristics so that we can take better advantage of computer technology in preparing fire behavior and fire-danger predictions. Four significant advances were made in fire modeling last year:

Another heat flux term added to rate of fire spread calculations. Scientists at the Northern Forest Fire Laboratory have evaluated fire spread rates through a fuel bed based on the energy conservation within the potential fuel ahead of the fire front. This evaluation determined that in addition to the forward heat flux, the vertical gradient of the propagating heat flux is also significant to the propagation of a fire. This is another step toward the development of fire spread models. - INT

Fire spread and intensity are predictable before the fire starts. Fire spread and intensity can now be predicted for small fires on calm days from a set of mathematical relationships. The information inputs are fuel loading, fuel particle size, fuel depth, moisture, mineral and heat content, and fuel particle density. - INT

Thermal radiation and integral scale of large experimental fires. The role of thermal radiation in modeling a mass fire is uncertain when smoke is present. Preliminary analysis of the mean depth of smoke from a large experimental fire gives values of 100 feet when the fire is burning at peak intensity. Also, spectral analysis and correlation of data from experimental fires indicate that the characteristic size of large fires is about 60 feet. This is related to the turbulence in the flow and the size of the gross fuel elements, and is important for a correct numerical grid in computer models. - PSW

Fifty-three important combustion-environment correlations identified. Analysis of the data from a program of small experimental fires has identified 53 important input-output simple correlations. This multitude of correlations illustrates the complexity of the combustion-environment relationship, and the multiple choice of output terms for scaling differences between fires. One example output term, total fuel consumption, correlates with total fuel loading, litter temperature, net radiation, and surface litter moisture content. Other output terms are: flame temperature indexes correlated with fuel geometry and air temperature; fire spread indexes correlated with windspeed, fuel geometry and aerial dead fuel moisture content; and time-fire temperature indexes correlated with available fuel and fuel geometry. - RM

2. Fire Chemistry

New tests for fire retardant treatments. A fire retardant study is attempting to develop new procedures for testing retardant chemicals. Due to the differences between glowing and flaming combustion, this study is proceeding along two lines. For glowing combustion we have modified a tobacco industry leaf-burn test which briefly brings a sample into contact with a small loop in a glowing nichrome wire. The test criterion is the time for glowing combustion to occur. A test apparatus has been developed to measure the burn area with an ultraviolet detection system. Susceptibility to flaming combustion is monitored by measuring the evolution of combustible vapors from the progressive pyrolysis of vegetative fuels. The pyrolysis products are carried over a cracking coil by an inert carrier gas, mixed with air, and then drawn through a combustible gas indicator. Results from these tests determine the effectiveness of fire retardant chemicals separately for each of the two types of combustion. - PSW

Crude fat contents differ significantly between species. A fuel chemistry study in Arizona found that the crude fat content differs between plant species by as much as 100 percent. Also, it differs between seasons within species by as much as 20 percent. This study will now conduct fire experiments in the laboratory to determine the effect of crude fat content on flaming combustion. - RM

A new method developed for determining amount of iron in plants. A wet digestion and calorimetric technique is now available to determine small amounts of iron in plant tissues. With a volumetric flask for weighing, digestion and dilution, the wet digestion is performed using a mixture of sulphuric and nitric acids. This new technique will speed studies of the effect of mineral content on combustibility of plant tissues. - PSW

Accomplishments in fire chemistry research from Israel project. A Public Law 480 project in Israel has developed a simple technique to collect radioactive CO_2 under reduced pressure for liquid scintillation counting. This technique permits the assay of small amounts of both radioactive CO_2 and CO that are evolved by the pyrolysis of labeled carbohydrates under reduced pressure. Using this technique, scientists on the project determined how cellulosic materials break down and recombine in the combustion process. Results from this project are increasing our knowledge of the basic processes that take place during the pyrolysis of cellulose, the first step in the combustion of woody materials. - WO

C. Fuels and Fire Behavior

1. Fuels

The use of herbicides in prescribed burning. Small woody stems must be dried to their equilibrium water content when using herbicides to assist in prescribed burning operations. A study of single spray application herbicides found that the drying rate slowed markedly if defoliated stems were connected to a living root system. This keeps the stem moisture above atmospheric equilibrium for prolonged time. Another study of ways to desiccate manzanita brush found that an application of a mix of 2,4-D and 2,4,5-T in November 1966, plus an application of paraquat in early June 1967, dried both leaves and fine twigs of the manzanita by the end of June and 1/4 inch stems by October. Continued drying reduced the moisture content of the leaves, twigs, and stems under 3/4 inch to about 15 percent by April 1968. These methods of lowering the moisture content can facilitate prescribed burning to remove manzanita brush. - RM

Techniques for the quantitative measurement of fuel. A fuel study in Montana has developed techniques for the quantitative measurement of fuel volume, surface area, particle size, particle density, fuel loading, porosity of the fuel complex and orientation of particles. The study tested these techniques in both cheatgrass and ponderosa pine forest floor fuels on an experimental plot basis. Results show that the number of particles intersecting two dimensional planes can accurately estimate the fuel volume and surface area provided either the particles or planes are randomly positioned. - INT

Seasonal and diurnal variations of moisture content determined for pocosin shrubs. Scientists at the Southern Forest Fire Laboratory have found that the moisture contents of both stems and foliage from six species of pocosin shrubs reach their lowest levels during the fall and early spring. The moisture content of most species increases rapidly through May, reaching a maximum during the first two weeks of June. The moisture content of new foliage exhibits a noticeable diurnal fluctuation with maximum moisture contents occurring between 2 and 6 a.m. and minimum occurring between 2 and 6 p.m. This will help determine when fuels are most flammable. - SE

Starch and sugar content in saw-palmetto. Starch is the principal storage carbohydrate in the rhizomes of unburned saw-palmetto plants, and is in highest concentration in the winter. A study has found that when the fronds are removed by fire, the starch content decreases sharply, the sugar content increases more slowly, but the total carbohydrate concentration decreases. The plants recover within 4 years after a single burn, indicating that fire will have to be applied repeatedly when starch reserves are lowest if saw-palmetto kill is to be accomplished by fire alone. These results will help determine when best to use fire to eliminate understory vegetation. - SE

Killing scrub oak with herbicides. Scrub oak has always been a tough plant to kill. A fuel hazard reduction project in California compared individual sprouting plants after they were hand sprayed with either brushkiller (2,4-D) or picloram. The brushkiller killed less than 30 percent of the scrub oak plants while the picloram killed 90 to 100 percent. Only a 60 percent kill of scrub oak with brushkiller was obtained even after three annual applications.

In contrast with spray applications, "inconsistent" describes the response of scrub oak to stump-applied herbicides. A 75 percent kill of plants treated with dimethylamise salts of 2,4-D was obtained in November 1964, 17 percent kill in November 1966, and 96 percent kill in January 1967. Results with other herbicides also varied from year to year although in a different pattern. In general, 2,4-D amine seems to be the best herbicide other than arsenicals and January the best time to treat stumps. These results will be useful to those attempting to reduce this type of fuel in hazardous areas. - PSW

Moisture content and firebrand flame characteristics both effect ignition. An ignition study in Georgia has determined that the levels of moisture content that cause ignition probability to drop below 100 percent for slash pine litter beds are highly dependent on the firebrand flame size and duration. The flame from three wooden kitchen matches bound together produced 100 percent ignition when fuel moisture contents were less than 20 percent and rarely caused ignition when moisture contents exceeded 35 percent. The flame from a miniature wooden match produced 100 percent ignition when moisture contents were less than 15 percent and rarely ignited the fuel when moisture content exceeded 25 percent. These results will be helpful to the development of an ignition index in the National Fire-Danger Rating Systems. - SE

The physical characteristics of chamise. The extensive distribution of chamise makes this chaparral species one of the major wild land fuels in the Pacific of physical data of the entire chamise shrub that the fuel sizes combined with the fuel bed porosity contribute greatly to the flammability of this fuel type. Moisture content of the living material reaches a maximum in the spring growing season and a minimum in late fall when the shrub is dormant. The crude fat content increases during the fire season, reaching a maximum in the fall. The large amount of fine material, the porous nature of the fuel bed, and the lowest fuel moisture and maximum crude fat content coinciding with the period of worst fire weather makes chamise one of the most hazardous fuels in southern California. - PSW

2. Fire Behavior

Features of mass fire defined. Researchers have conducted an intensive study of one of the major fires that occurred in the Northwest in 1967. This study determined that there were five features of a mass fire system associated with this fire. They were: (1) simultaneous ignitions caused by flying firebrands; (2) high energy output; (3) strong fire-induced winds; (4) violent firewhirls and erratic wind behavior; and (5) strong vortex action downstream from the burning area. Calculations showed a high probability that firebrands traveled more than 12 miles; fire intensity reached 470 million B.t.u./sec.; and induced winds exceeded 80 m.p.h. The conditions necessary for a mass fire in a coniferous forest include continuous fine fuels, sustained drying conditions, relative humidity less than 30 percent, and ambient winds greater than 20 m.p.n. - INT

Fire flareup causes fatalities. Eight firefighters were trapped and fatally burned in a fire flareup in the Canyon Fire in Los Angeles County on August 24, 1968. A study initiated immediately after the incident determined that light, fluctuating winds, unstable atmospheric conditions, a heavy accumulation of very dry fuels, and steep, broken topography produced a situation very conducive to sudden flareups. These findings reemphasize the great danger from topography-dominated fires in potentially fast burning fuels. - PSW

Heat-resistant anemometers developed for fire behavior research. The Forest Fire Laboratory at Riverside has developed heat-resistant anemometers that are capable of measuring both horizontal and vertical airflow within a fire environment. Developed to aid fire behavior studies these anemometers will continue to operate as long as the anemometer body remains cooler than 650°F. This means they can survive brief immersions in flame without damage. Low in cost, they are suitable for normal as well as high temperature use. - PSW

D. Fire Prevention and Use of Fire

1. Fire Prevention

Experimental fire prevention materials successful with the young. A study in California tested new fire prevention and conservation education materials on Butte County kindergarten through third grade children. Results showed that the children of all grade levels learned more information and retained it longer when using the new materials. The kindergarten and first grades had the highest gains. - PSW

Children who set many fires found to have other problems. A Geroge Washington University study supported by the California Division of Forestry found that children who set more than one fire have a wide variety of other behavioral problems and live in a disturbed family setting. Also, the children have psychosomatic disorders and organic symptoms characterizing minimal brain disfunction. - PSW

Enforcement of forestry laws affects fire rates. Researchers in Mississippi have found that the enforcement of forestry laws and fire rates vary widely between counties. Their study of selected counties revealed that sheriffs who scored highest on knowledge of forestry and its laws were from low fire rate counties. The numbers of forestry-related court cases were directly related to fire rate even though sentences were consistently suspended. Carrying out the judicial process even without punishment seemed to be a deterrent to firesetting. - SO

Responsible attitudes and social structure of the Utah forest user. A study of the man-caused forest fire problem in Utah County, Utah has determined the social factors which correlate with attitudes toward responsibility. Results show that the most responsible attitudes are among the older, urban, fire-experienced, authority-tolerant, and fire-knowledgeable persons. They also show that the characteristics of the forest users are related to their knowledge and attitudes regarding protection of forest resources from fire. Nearly eight out of 10 of the Utah County residents visited a National Forest at least once during the year preceding this study. Their mass communications sources of forest fire knowledge in order of importance are television, radio and newspapers. Smokey the Bear is the most frequently remembered item from these sources. The scientists concluded that: fire prevention programs must be geared to all the people; special attention should be given to active users of the forest who are ill-informed and poorly motivated regarding the use of fire; and stress should be placed on the fact that the National Forests are their forests. These results will provide direction to the fire control manager's prevention program. - PSW

2. Use of Fire

Air pollution from slash burning can be minimized. Scientists at the University of Washington investigated the relationships between slash burning and air pollution with both broadcast and laboratory fires. Results suggest that broadcast fires can be modeled in the laboratory with respect to burning characteristics and gaseous and particulate emissions. Also, results showed that noxious gases and hydrocarbons diluted rapidly to ambient values. particulate emissions in the smoke plume were high, but decreased to normal values within 12 to 15 miles of the fire. - WO

Logging slash burns provide information on seed bed preparation differences and vegetation recovery. The Northern Forest Fire Laboratory has conducted broadcast burns in experimental blocks of Douglas-fir logging slash to quantify differences in duff removal and lesser vegetation recovery. Before burning the logging slash, noncommercial residue and organic soil mantle averaged 64 tons per acre, and the duff layer was 1.85 inches deep. Spring burning consumed only half as much duff as autumn burning, but there was no significant difference between burning one year versus another. There was a 35 to 40 percent recovery in lesser vegetation by midsummer of the year following burning. - INT

A "hot" fire prescribed to consume duff. Researchers in Arizona developed a prescription for a fire that will consume three-fourths of a 2 to 3 inch layer of duff in ponderosa pine and still leave enough cover to prevent soil erosion. A test of this prescription on one fire consumed 70 percent of the duff in one area and 73 percent in another area. The fires produced other beneficial effects including thinning of the overstory from below, increased seedling germination, and a temporary reduction of the fire hazard. - RM

Prescribed fire used for wildlife habitat management. A survey of prescribed burning operations in Minnesota, Wisconsin, and Michigan showed that over 14,000 acres of land were treated with prescribed fire during 1968. Treatment costs varied widely from $0.32 to $13.00 per acre, and were directly related to man-hours expended on control and indirectly related to size of area burned. A research study of treatment costs could reduce this difference in costs and result in substantial savings. The purpose of 93 percent of the prescribed fires was either improvement or maintenance of wildlife habitat. - NC

Water system developed for prescribed fires. A primary requisite for prescribed fire is capability to control the fire. Research has developed a high-capacity water pumping and distribution system designed to control fires over the full range of environmental conditions established for prescribed fires. Initial field tests show that the system produces a water curtain 55 feet high, 150 feet wide, and 1500 feet long with 1/4 inch nozzles spaced 20 feet apart and under 80 p.s.i. of pressure. This system will reduce the control costs of prescribed fires and raise the upper limits of environmental conditions for conducting these fires. - NC

Nighttime burning removes slash and litter. A study in Georgia found that nighttime burning can successfully reduce the fuel hazard in young plantations and thinned pine stands. It can consume logging slash up to 1/2 inch in diameter and reduce litter fuel as much as 75 percent with little or no damage to the overstory. As more than 9 million acres have been planted to pine trees in the South during the past decade, the control of hazards is now an extensive problem. Due to the limited number of daytime burning days, nighttime burning can be an important aid to the solution of this problem. - SE

Maximum temperature in the cambium of sweetgum trees can be predicted. Scientists can now use bark thickness, stem diameter, initial cambial temperature and fire intensity to predict maximum temperature in the cambium of sweetgum trees treated with prescribed fire in the winter. About 90 percent of all stems 4 inches d.b.h. and less died following fire intensities of 1.5 B.t.u./sq. in. for a period of more than 30 seconds; less than 25 percent of the stems died when intensities were below this level. These results will help determine the prescription for fires used to control small sweetgum. - SE

E. Fire Control Methods and Systems

A computer based forest fire dispatch system tested in California. The Forest Fire Laboratory in Riverside developed a computer-based forest fire dispatch system. The system determines the minimum travel routes for fire equipment. They tested the system in the California Division of Forestry, San Bernardino County Ranger Unit, during August and September 1968. The prototype system was determined a technical success, but prohibitively expensive. - PSW

New infrared forest fire detector developed. The Northern Forest Fire Laboratory has designed and fabricated a more refined airborne infrared fire detection system that uses both an indium antimony and a mercury germanium detector with in-flight, real-time correlation of the dual output. The 8 to 14 micron portions of the signal from this system provides a higher quality terrain imagery than the 3 to 6 micron signal alone, employed in the system used in 1967. Correlation of the two signals enhanced the fire target-to-background discriminating ability by a factor of 3 to 4 over the 1967 system. This improved system will detect fires that might otherwise go undetected and later burst into large destructive fires. - INT

Spread index and buildup index interpretations for coastal Alaska. Researchers in Alaska compiled the spread index and buildup index values for selected coastal Alaska stations for the period 1956-65. They developed 10-year normal index values to allow seasonal comparisons with a standard base. Differences encountered among stations suggest that available personnel, equipment, and facilities related to danger rating levels should be distributed on the basis of areas that have relatively uniform fire danger characteristics or by individual stations. This information helps improve fire planning to reduce fire control costs and fire losses. - PNW

Forest fire suppression manpower model developed. A project in Washington has developed an economically based mathematical method to determine the optimum level of forest fire suppression manpower on a seasonal basis. First, they developed a simulation model of forest fire protection activity. Then they tested this model with data from a hypothetical forest to determine the rationality of the functional relationships. Finally, they applied the model to an administrative unit of the Washington State Department of Natural Resources. Conclusions of the study are: (1) the model can be used to determine an optimum level of manpower by simulation of forest fires occurrence and suppression activity; (2) the model is immediately useful as an aid to decision making; and (3) the data presently available on most forest management and administrative units is not the quality required for more than only rough approximations. - PNW

Inexpensive scanners developed to detect fires. Project Fire Scan has developed and flight tested an inexpensive fire spotting scanner that uses an uncooled detector and a commercial-quality spherical primary mirror. The readout consists of five lights that indicate the presence and relative location of a fire target with respect to the aircraft. This scanner can be used by helitack units, smokejumpers and lead planes to locate fires that are not putting out enough smoke for visual detection. This will permit large savings of man-hours lost by initial attack forces trying to locate this type of fire. - INT

Simulated forest fire detection systems analyzed. Researchers have developed one approach to the problem of defining the most effective lookout-aircraft forest fire detection system for a specific budget. They used probability distributions of fire and weather based on past data to produce a forest fire detection environment. Then they simulated many feasible all-lookout, all-aircraft, and combined lookout-aircraft detection systems within the specified environment. Each alternative was constrained by a fixed budget, and evaluated in terms of a common criterion. In the last step of the solution they examined five budget levels against hypothetical fire data, and identified the most effective alternatives. This information can be very valuable to Federal agencies and State governments faced with the problems of deciding on the best type of detection system for an administrative area. - INT

Models prepared to establish the effects of fires. A research project in Missouri has prepared a set of models that establish the relations among the direct, indirect and economic effects of fire. These models will be used to guide the collection and interpretation of data for damage appraisal. Whereas timber and range resource models are well established, watershed, recreation and wildlife models are specified for the first time. The development of these models marks an important step forward in multiple resource fire damage appraisal. - NC

Hardwood trees used as fire barrier. A firebreak study is developing hardwood fire barriers as a technique for stopping crown fires in high-hazard, even-aged conifer forests. They found differences in the survival and growth rate between 15 hardwood species planted on droughty jack pine sites in Michigan and Wisconsin after two growing seasons. Two aspen hybrids developed by the Institute of Paper Chemistry had 100 percent survival and excellent growth. Honey locust, American elm and Russian mulberry had above-average adaptability to the sites. - NC

Analysis of climatic conditions preceding disastrous fires provides warning indicators. Knowledge of the climatic conditions preceding disastrous fires provides a reference base for recognizing trends toward such situations. A study of the climate that preceded seven disastrous fires in Michigan, Minnesota and Wisconsin found that: (1) precipitation was far below normal for 3 to 8 months before each fire; (2) the weather was not usually hot before each fire; (3) agricultural drought data indicated vegetation to be below the wilting stage for 40 to 75 days preceding each fire; and (4) the humidity was below normal for lengthy periods before all but two of the fires. - NC

A computer program evaluates fire-danger indexes. Researchers have completed a total system computer program that empirically evaluates various fire-danger indexes relative to actual fire business. Results may be obtained for specific fuel types, seasons and weekday-weekend periods using various fire activity criteria. Initial tests of the current national spread index produced extremely high linear correlation between the fine fuel spread index and the probability of a fire day in Minnesota, Michigan, and Wisconsin. Computerized timber fuel spread index data proved to be an excellent predictor of the number of fires per day in the three-state area. The burned area criteria produced a low correlation with all index forms. This computer program will be a useful aid to the evaluation and local interpretation of the National Fire-Danger Rating System that is scheduled for completion next year. - NC

Experimental fire retardant ground tanker completed. The Southern Forest Fire Laboratory has completed modification of a truck that will be used as a ground tanker in fire retardant chemical application rate experiments. The pump output, nozzle stream configuration, and tanker speed can be controlled for accurate application of the chemical. This tanker will provide a boost to fire retardant chemical application rate experiments in different fuels. - SE

National fire-danger rating system structure. Scientists in Colorado have redeveloped the structure for the national fire-danger rating system. The burning index is the most important part of this system, and is defined as the relative measure of the potential control job for an average fire in a rating area. It is based upon the potential relative rate of fire spread plus the rate of energy release. A relative measure of the total daily fire load for the rating area is obtained by combining the burning index with the probable number of fires. The results from this project will be a fire-danger rating system available in whole or in its separate parts to all Federal and State agencies. - RM

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FOREST INSECT AND DISEASE RESEARCH

FOREST INSECT RESEARCH

Problems and Objectives

Increasing demands for the Nation's forest resources -- including wood products, wildlife, water, recreation, and environmental enhancement -- necessitate greater protection against insects and other destructive agents. Insects adversely affect tree growth and quality from the time the seed germinates until harvest. Also, the use and value of the derived products may be reduced. The dynamic changes in land use patterns, forest management practices, and economic and aesthetic values, as well as advances in our technology, must be constantly reviewed to assure that on-going insect research programs will provide solutions for the more pressing problems.

Major objectives of forest insect research are:

1. To obtain a better knowledge of specific pests and their interrelationships with one another and the forest environment.
2. To develop improved methods for detecting, evaluating, and predicting forest insect infestations.
3. To develop less expensive, longer-lasting methods of controlling pest insects and/or the damage caused by them through cultural, biological, and chemical means.

Progress

A. Biology and Ecology

1. Bark beetles. Data analyses from aerial photo and ground sampling of an epidemic of western pine beetle on the Shasta-Trinity National Forest in California have proven useful in developing population trend predictions. Beetle numbers and damage were greatest on the best sites supporting overstocked stands. Stand improvement is suggested. - PSW

Overcrowding and competition for the same inner bark food supply are important limiting factors for the Douglas-fir beetle in western Oregon. The presence of other inner-bark feeders does not seriously affect survival of the beetle. These findings must be taken into account in predicting population trends of the pest. - INT

Studies of the influence of logging residues on Engelmann spruce beetle outbreaks have revealed that the north sides of stumps, undersides of cull logs and tops, and the placement of material in cool, shaded locations all provide situations suitable for high brood survival and population increases. These favorable conditions may last for at least 2 years after logging. - RM

Examination of many engraver beetle infestations in red pine plantations in Michigan revealed that increased slash accumulations, damaged residual stems, and below normal rainfall all contributed to widespread outbreaks of this insect. - NC

2. Defoliators. Overwintering larvae of the large aspen tortrix become active in early May and complete their development by early July in interior Alaska. Food quantity and quality are major factors in population fluctuations. Starvation in the last larval instar is extremely important in survival and fecundity. - PNW

Hemlock sawfly larvae usually do not feed on current-year hemlock foliage unless forced to do so following depletion of old needles. Laboratory studies reveal that when forced to feed on current-year foliage or bare twigs, there is a marked increase in mortality, particularly of females. Surviving females produce fewer eggs than those developing on old needles. This apparently accounts for the abrupt decline of sawfly populations following severe defoliation. - PNW

The lodgepole needle miner in Inyo National Forest begins its 2-year cycle in even-numbered years. By contrast, the needle miner in Yosemite National Park, 30 miles to the west, begins its cycle in odd-numbered years. There are no overlapping generations at either location. - PSW

In the northern Rocky Mountains, the spruce budworm severs new shoots of western larch. It also damages cones and seeds. Apparently the larvae move to the cones after feeding for a time on the larch foliage. - INT

Vulnerability of balsam fir to damage by the spruce budworm in northeastern Minnesota seems to be affected by stand characteristics similarly as in the Northeast. No individual characteristics have been found that will serve as reliable predictors of susceptibility. - NC

The Great Basin tent caterpillar overwinters as a fully-formed first instar larva within the egg case. Hatching begins in late May and the larvae feed for 32-40 days. Following pupation, adults lay eggs from mid-July to early August in masses of up to 250 eggs. Heavy defoliation of aspen for 3 consecutive years reduces radial growth by 75 percent. Defoliation also reduces aesthetic and recreational values of aspen stands, and the foliage and insect debris contaminates water supplies. Tent caterpillar infestations have significantly limited commercial production of aspen in the Southwest. - RM

Biological studies of the white-fir needle miner in California red fir disclosed that it has a 2-year life cycle and overlapping generations in contrast with a 1-year cycle in white-fir in southern Utah. In California, there is no evidence of permanent injury from insect feeding as there is in Utah. - PSW

In 1957 and 1958, populations of the spruce spider mite, occurred on nearly a million acres of Douglas-fir which had been treated with DDT in 1956 and 1957 to control the spruce budworm in western Montana. Fifteen other species of mites were associated with the spruce mite. - INT

The Siberian pea shrub (Caragana) is an important, long-lived component of shelterbelts in the Great Plains. Early summer defoliation by blister beetles, late summer defoliation by grasshoppers, and premature leaf fall due to a leaf spot fungus cause considerable damage to this species. - NC

3. Borers and tip-feeding insects. A cooperative mill study with the Ohio Division of Forestry revealed that 13 percent of the volume in merchantable white oak logs was damaged by at least one species of borer. Insects included the white oak borer, carpenterworm, and the red oak borer. Carpenterworm attacks were primarily associated with unsound knots or roundheaded borer attacks. Over 60 percent of the insect-caused damage could not be identified. - NE

4. Sucking insects. Development and hatching of eggs of the balsam woolly aphid, occurs at temperatures ranging from 5° to 30° C. Hatching success and crawler survival are highest at intermediate temperatures. Humidity also has a pronounced effect on incubation period, hatching success, and crawler survival. Freezing has little effect on hatching unless temperatures drop below-8° C. - SE

An aphid, Pineus sp., has been found in scattered stem infestations on red spruce located on Roan Mountain and Mt. Mitchell, North Carolina. There are two generations per year. The aphid overwinters primarily in the penultimate instar. Egg laying begins in early May. Females lay a maximum of 17 eggs in a cluster. In appearance, the insect closely resembles the balsam woolly aphid. - SE

5. Cone and seed insects. Sugar pine cone beetles survive seasons when cones are not available or even years of cone crop failure by entering a resting period in old cones and twig tips. Normally, they are well adapted to breeding in sugar pine cones and going from cone to cone establishing broods. Knowledge of this flexibility in the biology of this pest is important in predicting extent of damage and how it can best be controlled. - PSW

Leptoglossus occidentalis feeds upon developing seeds within maturing ponderosa pine cones from May to October. The type of damage varies with stage of development of the seed. Feeding may affect up to 55 percent of the seeds. PSW

Second-year red pine cone crops are severely damaged by several species of insects. These include Conophthorus resinosae, Dioryctria disclusa, Eucosma monitorana, Laspeyresia toreuta, and Rubsaamenia sp. Control of the first two insects would increase seed yields in most seed-production areas by at least 50 percent. - NC

A seed chalcid can cause severe loss of Fraser fir seed. During poor seed years, this may account for as much as 1/3 of the crop whereas in good seed years, losses are far less significant. - SE

Systematic observations of first-and second-year cones on open-grown shortleaf pines has provided seasonal attack patterns of insects causing cone mortality and seed loss in the Southeast. Early attack by the Nantucket pine tip moth accounts for appreciable mortality of first-year cones. Second-year losses are due primarily to coneworms and midges. - SE

6. Bark-feeding insects. Adults of the pine root collar weevil remain at the base of the host tree during the daytime where they feed, mate and oviposit. At night they feed on the bark of branches on the same tree or move to other trees primarily by walking. - NC

In coastal North Carolina, broods developing from eggs deposited by both pales weevil and the pitch-eating weevil in early spring through May generally complete development and adults emerge prior to September or October. Broods from eggs deposited in June develop to the late larval stage which overwinters, adults emerging the following spring. - SE

7. Forest products insects. The fir tree borer causes serious degrade in lumber manufactured from windthrown white fir. Damage is caused by the larvae boring up to 3 inches into the wood. - PNW

B. Biological Control

1. Invertebrate parasites and predators. The most common primary parasites of the hemlock sawfly in coastal Alaska are Opidnus tsugae tsugae, Delomerista japonica diprionis, and Itoplectis quadricingulatus. Two other species, Amblymerus verditer, and Gelis sp., are hyperparasites. - PNW

The Eulophid, Elachertus aeneoniger, is a primary parasite of black-headed budworm larvae in coastal Alaska. Tetrastichus coerulescens, in turn, parasitizes the primary parasite. - PNW

In a first record of parasitism of adult Dendroctonus bark beetles, Karpinskiella paratomicobia parasitized 58 percent of the parent Douglas-fir beetles in Utah and Arizona. Parasitized females laid an average of 62 fewer eggs per beetle than did unparasitized ones. - INT

The introduced parasite, Dendrosoter protuberans, is well established as a parasite of the smaller European elm bark beetle in the central states. Parasitism ranges from 23 to 37 percent in Missouri and Ohio. - NE

Three native parasites, Spathius canadensis, Cheiropachus colon, and Entedon leucogramma, commonly occur in elm wood infested with the smaller European elm bark beetle. The first two species oviposit through thinner bark but E. leucogramma enters the beetle gallery and oviposits on the host eggs. - NE

Trees were examined in 1968 to establish the status of foreign predators released at 20 sites on Mt. Mitchell, North Carolina, for control of the balsam woolly aphid. Immature and adult stages of Laricobius erichsonii were found actively feeding on the aphid and a species of Pineus on red spruce. It is assumed that other introduced predator species failed to become established.

The predator, Leucopis obscura, introduced into New Brunswick, Canada, in 1933, has spread to and become established over the entire range of the balsam woolly aphid in Maine. - SE

Continuing surveys of parasites and predators of the southern pine beetle in North Carolina reveal that these organisms collectively reduce beetle populations by at least 30 percent. - SE

Ninety-five species of mites are associated with southern pine bark beetles in an outbreak area in central Louisiana. Six are known predators and several others are suspect. - SO

A rearing method has been devised at Corvallis which permits the recovery of a large number of decocooned greater wax moth pupae for use in large scale rearing of pupal parasites. Mature larvae are confined within an electrically charged barrier in metal cocooning trays. The larvae spin their cocoons. Pupae are recovered by immersing the trays in a sodium hypochlorite solution which dissolves the cocoons without injuring the pupae. - PNW

2. Vertebrate predators. Three species of woodpeckers, the three-toed, the hairy, and the downy, have ranges that coincide with Engelmann spruce and spruce beetle distribution. Of the 3 species, the three-toed woodpecker is almost entirely restricted to spruce stands and is the most important spruce beetle predator. Woodpecker efficiency and population density vary with size of beetle population. Woodpecker predation accounts for up to 84 percent of the mortality occurring in spruce beetle populations. - RM

3. Insect pathogens. A zonal purification technique has been developed for the mass purification of nucleopolyhedra occurring in virus-infected Douglas-fir tussock moth larvae. Pure gram-amounts are currently being used in biological, biochemical, and biophysical investigations. This purification technique is directly applicable to the production of viruses for the control of several other important forest defoliators. - PNW

A joint effort with the MAN ultricentrifuge unit at the Oak Ridge National Laboratory using their batch zonal ultricentrifuge has produced highly concentrated, purified polyhedral preparations. Further work will lead to automation of the entire polyhedral cleanup procedure for the viruses of the

European pine sawfly and gypsy moth. Over 50 grams of extremely clean concentrated polyhedra of the former virus has already been obtained for field and laboratory studies. - NE

A detachable helicopter spray system for ultra-low volume application of microbial sprays has been developed by the Pacific Northwest Station and the USFS Missoula Equipment Development Center. Application rates in the air can be changed from about 0.1 to 0.5 gals.per acre without changing spray atomization. Spray atomization can be changed by varying the spinning rate of the atomizing devices. - PNW

Uniform batches of spores and crystals of Bacillus thuringiensis, free of cellular debris, can now be produced in the laboratory. Growth and sporulation takes place in the same liquid medium resulting in a 1:1 spore to crystal ratio. - NE

Studies are continuing on the pathogenicity and mode of action of the bacterium, Basillus thuringiensis var. thuringiensis, in larvae of the western hemlock looper, Douglas-fir tussock moth, and western tent caterpillar. The loopers were most susceptible to bacterial crystals alone, while the tussock moths and tent caterpillars were susceptible to preparations of bacterial crystals and spores combined. - PNW

Nucleopolyhedral counts and size-frequency distributions have been determined for the Douglas-fir tussock moth virus with a Coulter transducer. This technique will have immediate application in standardizing mass-produced nucleopolyhedrosis virus of this insect and similar viruses of other pest insects. - PNW

Surveys of pathogens of the southern pine beetle in North Carolina revealed that 22 percent of the brood died from disease. Laboratory tests indicated that the fungi, Aspergillus flavus, Beauveria bassiana, and Fusarium solani, and a bacterium, Pseudomonas sp., were pathogenic to the insect. Work continues to determine the pathogenicity of other bacteria, yeasts, and fungi recovered from dead beetles or their galleries and to define environmental conditions favorable for their establishment and growth. - SE

C. Chemical Control

1. Insecticides. In a cooperative study with the California Region of the Forest Service, researchers found that a 1.5 percent concentration of lindane in diesel oil was highly toxic to western pine beetles overwintering in the bark. Mortality averaged 95 percent in treated felled trees. Water emulsions were as effective as diesel oil formulations. - PSW

Zectran and naled were applied to late instar spruce budworm and associated insect populations on two small drainages in Montana. Zactran, applied at the rate of 0.15 lb. technical per gallon per acre, killed 92 percent of the budworm larvae. Naled, applied as a low-volume concentrate at the rate of 0.41 lb. per gallon per acre, killed an average of 42 percent of the budworm. Zectran was more selective than naled in that it reduced budworm populations to a greater extent than it did most populations of associated insects. - PSW

Zectran was tested on spruce budworm, tobacco hornworm, and housefly larvae in the laboratory and found to be highly toxic to the spruce budworm but considerably less toxic to the other two insects. - PSW

Six insecticides were tested in the laboratory against larvae of a pine tussock moth, *Dasychira* sp., from eastern Montana. The contact toxicities in descending order were: Zectran > malathion > DDT > SD-8530 > carbaryl (Sevin). PSW

A comprehensive series of fall and early spring treatments of methoxychlor, are planned in Milwaukee to decisively evaluate its effectiveness in preventing feeding by the elm bark beetle. Conclusions and control recommendations drawn from the study will be limited in scope until similar tests can be conducted in other geographic locations. - NE

Water-emulsion formulations of 0.12, 0.5, and 1.0 percent dimethoate provided 69 to 98 percent control of the pinyon needle scale in Arizona and Colorado. The spray was applied to all egg-mass concentrations when the eggs began to hatch. - RM

Cooperative pilot tests with Forest Pest Control personnel in Region 5 showed that dimethoate applied as a water emulsion at the rate of 2 gallons per tree in late May effectively protected ponderosa pine seed crops from destruction by the pine seedworm. No adverse effects on cones or foliage were detected. PSW

Four systemic insecticides, Bidrin, Meta-Systox-R, Cygon, and Monitor, were field-tested against coneworms and the slash pine seedworm in second-year slash pine cones. Applied at the rate of 5 grams active toxicant per inch of tree diameter, these chemicals reduced coneworm attacks by 80 to 89 percent. Bidrin and Meta-Systox-R, applied at the same rate, reduced seedworm damage by 97 and 95 percent, respectively. - SE

Four insecticides -- Gardona, Fenthion, Azodrin, and Trichlorfon -- were field-tested against the slash pine seedworm. Gardona provided the best control, followed by Fenthion. The former insecticide has low mammalian toxicity while the latter is moderately toxic. - SE

Two computer programs have been developed for numerically estimating spray properties. One program analyzes data on the number of drops falling in fixed diameter classes. The other program uses the total number of spray drops in a sample whose diameter exceeds a fixed value. - PSW

Studies have been completed on initial soil penetration by insecticide emulsions used for subterranean termite control in seven widely dispersed areas across the United States. It was found that more than half of the insecticide was retained in the upper 3/4-inch of soil. - SO

A 1.5 percent formulation of lindane in diesel oil effectively controlled all stages of the California flatheaded borer. Mortality was particularly high among early instar larvae under the bark. The chemical remained effective for over 9 months on sprayed logs. - PSW

The Saratoga spittlebug can be controlled in the nymphal stage on sweet fern, its alternate host, with Baygon. Granular applications of this systemic may be made during a 6-week period from about 2 weeks before nymphal eclosion to just before adult transformation. - NC

Phorate applied as a soil drench around loblolly pine seedlings effectively controlled pales weevil and pine aphid damage for 480 days following application. - SE

Treatment of young cottonwood trees to control feeding insects with a systemic, phorate, increased pulpwood yield at age 8. Treated trees produced four more 4-ft.-long pulpwood bolts than untreated ones. - SO

Texas leaf-cutting ants quickly reinvade areas that have been treated to destroy their nests on upland sites in Texas and Louisiana. The rate of reinvasion averaged one nest annually on every three acres in a recent study. Although survival of the new nests was erratic, some quickly became large enough to cause serious damage to pine reproduction. To minimize losses, annual treatments of the nests are needed until the pines reach about 15 feet in height. - SO

2. Chemosterilants. A technique has been devised for mating up to 36 percent of the European pine shoot moth females placed in laboratory cages for a stipulated time period. Production of a sex attractant was necessary to stimulate mating. Females were found to mate only once during their lifetime. The mating technique will be used in studies aimed at evaluating irradiation dosages by mating sterilized males with normal females and determining egg fertility. - PNW

D. Other Control Methods--Host resistance, site and stand manipulation, attractants.

Evidence continues to show that xylem resin quantity and quality and beetle attack density affect the degree of resistance of ponderosa pines to forced attacks of western pine beetle. As beetle attack density increases and resin quantity decreases, tree resistance decreases. With lower beetle attack densities and resin quantity, tree resistance seems to be associated with resin quality. - PSW

Studies of the attack pattern of a complex of needle-mining midges in relation to time of bud burst in Douglas-fir have suggested a method of cultural control for high-value Christmas tree plantations. Since the midges lay their eggs on newly expanded buds, the selection of plantation trees from parents having late bud bursting characteristics should permit Christmas tree growers to significantly reduce damage caused by this insect group. This approach would also make time of bud burst more uniform thus facilitating chemical control timing. - PNW

A field procedure has been developed for delivering and assaying attractants. With it, both sexes of the western pine beetle were attracted by the female-produced attractant, exo-brevicomin. Response of the beetle was improved by adding a host constituent, myrcene. One of the principal insect predators of the beetle, Temnochila virescens chlorodia, was also attracted by exo-brevicomin. - PSW

Continuing laboratory experiments with mountain pine beetle attractant fractions confirmed that males are more responsive to the female-produced material than are females. Test procedures are being refined to more critically evaluate beetle response. The influence of temperatures on flight response is receiving special attention. - RM

The attractant produced by pioneer Ips engraver males boring into new hosts attracts both sexes of this bark beetle. The responding insects, in turn, attack the host and attract additional beetles. Optimal response occurs at 90-94° F., 50-79 percent relative humidity, 21-40 foot candles light intensity, and wind speeds of 1.5-2 mph. Even under the most favorable conditions, less than 10 percent of the beetles within a 100 ft. radius are attracted to the attraction centers. - SE

A trail-following pheromone of the subterranean termite has been isolated, identified, and synthesized at the University of Wisconsin. The pure chemical will be used in further biological and behavioral research which may lead to a biological control method. - WO

Experimental thinnings have been made in eastern Oregon to determine whether mountain pine beetle outbreaks can be prevented by reducing stand densities to below naturally regulated levels. It has been shown that ponderosa pine mortality caused by this insect is greatest in denser stands growing on poor to fair quality sites. - PNW

Sanitation-salvage cuttings made in western Montana in 1956 and 1957 to remove high-risk, beetle-susceptible trees reduced tree losses due to western pine beetle by 72 percent during the following 10 years. Mortality was reduced only 5 percent by random selection cuttings which removed the same volume of timber. - INT

A six-year study of the effects of stand composition on tulip tree scale damage has shown that alternating red pines with yellow poplars within and between rows reduces insect dispersal by as much as 70 percent. Also, only 1/2 as many poplars die from insect feeding in mixed stands. Distortion of the remaining stems is reduced from 41 percent to 7 percent by mixing the species. - NE

During each of four years, southern pine beetle outbreaks in southeast Texas occurred primarily on imperfectly (Caddo series) and poorly drained (Rains series) soils largely forested with pine-hardwood mixtures. Most stands were well to excessively stocked and had a site index exceeding 80. In order to continue to grow pines on these sites, land managers should take steps to improve drainage. - SO

In southwest Louisiana almost 1/3 of the southern pine beetle infestations start in lightning-struck trees. In July and August up to 90 percent of the spots involve at least one lightning-struck tree. Damaged trees consistently show a marked reduction in oleoresin exudation pressure and flow. Prompt salvage or treatment of lightning-struck pines could reduce southern pine beetle outbreaks and spread into peripheral areas by as much as 25 percent. SO

At light intensities below 2 ft.-candles, the pine root collar weevil moves from tree base to branches or to other trees. Basal pruning and duff removal often provide high ground temperature conditions unsuitable for survival. Adults tend to shun pruned trees during a time when they normally mate and oviposit. - NC

Time studies are underway to determine the most efficient way to accomplish early basal-pruning for control of the pine root collar weevil and European pine shoot moth. Size class of young red pines, pruning shears vs. Meylan saws, and pruning vs. pruning and branch-duff removal are the treatment variables. - NC

E. Insect and Tree Physiology.

Bioassays have shown that the pales weevil is stimulated to feed by the lipid fraction of loblolly pine phloem tissue. Sugars combined with the lipids increase feeding activity significantly. Fractionation and bioassay of lipids revealed that polar lipids stimulate more feeding than do neutral lipids. Triphenyl-tin acetate, an antimetabolite, inhibited feeding at concentrations of 0.6 and 1.0 percent. - SE

Measurements of the xylem resin monoterpene composition of ponderosa pines revealed that there was virtually no change between positions along and around the trunk of the tree. Therefore, basal measurements of the major monoterpenes--alpha-pinene, beta-pinene, 3-carene, limonene, and myrcene--are representative of the whole trunk xylem system. - PSW

Oleoresin exudation pressure (OEP) is a physical factor that bark beetles must overcome in order to successfully attack a tree. In central Louisiana sawtimber stands under moisture stress, OEP was reduced more in trees on flat, usually wet sites than on adjacent low, 0.3-0.6m high, mounds. First attacks by southern pine beetle on large loblolly pines usually occurred on the flats. Thus, there was a correlation between beetle attack and moisture stress. - SO

Artificially imposed continuous flooding severely affected oleoresin exudation pressure (OEP) and these trees were all killed by bark beetles, principally the southern pine beetle. This points to the hazard of sustained moisture stress. - SO

Initial flow of resin in pines can be estimated by using capillary tubes inserted into holes drilled into the outer sapwood. Measurements are a quick, inexpensive means of evaluating resin flow potential and may be related to tree resistance to bark beetle attack. - PNW

Larval coloration in the western form of the spruce budworm is largely due to the presence of two chromoprotein pigments in the hemolymph--one blue and one yellow. The prosthetic group responsible for giving color to the blue pigment is a bile pigment. The group giving color to the yellow pigment belongs to the group of carotenoid pigments which are widely distributed in the plant and animal kingdoms. - PNW

Melanin is toxic to hemolymph cells in insect tissue cultures and can be prevented from forming. This is accomplished by: 1) chelation of the required copper ions by SH compounds, 2) substrate inhibition by competitive analogues, and 3) use of nonhomologous hemolymph which does not contain the melanin-forming system. - NE

F. Nutrition and Rearing

The smaller European elm bark beetle has been successfully reared through several generations on two artificial media containing no host plant material. Most of the nutritional requirements for the larvae have been determined with the exception of amino acids and vitamins. Twenty-one amino acids have been detected to date in the hemolymph of last instar larvae. - NE

Laboratory populations of the European pine shoot moth have been successfully reared through 10 complete generations at Corvallis. Improvements in the wheat germ diet have substantially reduced late larval mortality and the incidence of male sterility. A successful laboratory rearing technique is essential for tests and actual production of sterile males in laboratory and field control projects. - PNW

Mating efficiency can be increased by using moths of either sex which are less than 4.5 days old. Under optimum laboratory conditions pine shoot moth males mate a maximum of 6 times with an average of 2.24 times. This information is of importance in planning control operations utilizing techniques of male annihilation or sterile male release. - PNW

The meridic medium developed for rearing the coneworm, Dioryctria abietella was found to be suitable for rearing larvae of a closely-related species. The need for wheat germ was eliminated by increasing the protein content and adding alpha-tocopherol, linolenic acid, cholesterol, glycine, and cysteine. Further refinement is planned. Knowledge of the nutritional requirements of these insects is essential in studies of host selection behavior. - SE

An artificial diet has been used to rear the powder-post beetle in half the time it takes on wood. This will facilitate physiology studies and the development of more efficient control methods. - SO

The locust borer can be continuously reared on an artificial medium. In contrast with a normal life cycle of 1 year in the field, development from egg to adult has been reduced to 50 to 143 days in the laboratory. Percent survival is being improved through refinement of the diet. - NE

Methods have been developed to provide a year-round supply of mimosa webworm. During the summer, field-collected larvae are reared to the pupal stage on a semisynthetic diet. Pupae are held at 5° C. until needed. During winter, larvae are reared in the greenhouse on potted honey locust seedlings. - NE

G. Survey and Sampling Techniques

X-ray techniques have been developed for identifying and estimating numbers of the mountain pine beetle in lodgepole pine slabs of different thicknesses and moisture contents. The techniques will be tested on infested standing trees. Once refined, the method will greatly improve the precision and accuracy of sampling in population dynamics studies and in field surveys. - INT

Density of western budworm egg masses on needles of Douglas-fir can be most efficiently sampled by using a 24-inch branch as the sample unit. Sampling and evaluation can be accomplished in much less time than is required for the conventional half-branch sample. - RM

Sequential sampling plans have been developed for rapidly assessing the status of Douglas-fir tussock moth populations in chronic problem areas. The plans are aimed at distinguishing between currently innocuous populations and those having outbreak potential. Such plans can be used to sample either eggs or larvae but are most efficient for the latter. - PNW

European pine sawfly population levels can be indirectly estimated in young red and Scotch pine plantations. By sampling a specified number of trees, determining the proportion infested, and knowing in advance the population level at which control is needed, the need for control can be evaluated. - NC

Analyses have been made of the relationship between population density of the Columbian timber beetle in red and silver maple and temperature, precipitation, and number of days stands were flooded. Precipitation accounted for 61 percent of the variation in insect numbers. Flooding accounted for 19 percent, and temperature 12 percent. Thus, it can be predicted that major outbreaks of this beetle can be expected after 2 to 4 years of deficit precipitation during the growing season. - NE

Large-scale color aerial photographs (1:8,000) and a stratified two-stage probability sampling design have been utilized to provide an efficient survey of tree losses caused by the Douglas-fir beetle in California. Compared with other methods of obtaining mortality data, this technique produced more accurate results, required less time, and cost about $0.005 per acre. - PSW

An integrated closed-circuit TV and thermal infrared sensor system has been employed in providing a thermal profile of the terrain beneath a slow-flying helicopter. A videotape recorder obtained an overview of ground features and the precise areas covered by the infrared sensor. - PSW

Large-scale color photographs taken annually over a period of 10 years provided a good assessment of changes in balsam fir density in several spruce-fir stands in northern Minnesota. Northern tree species were identified with high accuracy. Phytographs based on photo images showed differences in tree species frequency, composition, and crown cover. - PSW

Four film types and five photographic scales were used in a feasibility test to detect smog-injured ponderosa pine near Los Angeles. Ansochrome D/200 color film was the best sensor at scales of 1:7,920 for detection and 1:1,584 for evaluation of damage. At the latter scale, exposures using a Didymium filter were considered superior to those using standard haze filters. December appeared to be the best month in which to correctly classify trees using this method. - PSW

Microdensitometry studies have helped improve the quality and versatility of aerial photography. Differences in lenses, films, and image motion can now be analyzed. Other applications include separations of soil from vegetation in range studies and water-depth determinations in shallow trout streams. PSW

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FOREST DISEASE RESEARCH

Problems and Objectives

All forest tree species are subject to disease. Forest diseases cause losses to timber estimated at 5 billion cubic feet of growing stock annually, including 20 billion feet of sawtimber or about 92 percent of net sawtimber growth. Disease losses in trees and shrubs important for forage, recreation and watershed values are also serious. In addition, disease agents reduce the value of wood products in use by an estimated 300 million dollars per year. Research must find ways to reduce these losses if we are to meet the ever-increasing demands for timber, water, wildlife, recreation, and esthetic values from the nation's forests.

Major objectives of the research are:

1. Determine causes of disease
2. Determine biology, ecology, and physiology of the causal agents
3. Determine factors affecting spread and prevalence
4. Develop effective controls

Progress

A. Seed and seedling diseases

Losses of several million red and scotch pine nursery seedlings annually in Lake Station nurseries is believed to be caused by the needle cast fungus, *Lophodermium pinastri*. This fungus has caused severe losses in northern European nurseries in recent years. Preliminary fungicide tests suggest that it will be possible to control this disease with chemicals. - NC

Most spores of the Scleroderris canker fungus are released within 24 hours following rainfall during the summer months. Attempts are being made to control this serious disease of red and jack pine in Michigan and Wisconsin. Knowing the time of spore release will permit researchers to concentrate their studies on the period when infection is most likely to occur. - NC

Although many nursery diseases can be controlled by application of fumigants and fungicidal sprays, a program of proper soil management can improve disease control. Studies have shown that early applications of nitrogen will increase growth of pine seedlings but also will increase the severity of certain diseases. If applications of nitrogen are delayed until after the risk of infection is minimal seedling growth will increase without a corresponding increase in disease prevalance. - SE

Periodic observations of diseases occurring on 10 species of North American trees planted in Poland were continued. Douglas fir was heavily damaged by several needle cast fungi and root rot has caused considerable damage on most of the introduced species. To date all diseases that have been observed are also present in North America and therefore do not constitute a threat to accidental introduction. - WO

B. Root diseases

1. Annosus root rot. A number of different materials have been tested in an attempt to develop a treatment for preventing infection of stump surfaces by *Fomes annosus*. Evaluation of some of these treatments has shown that the masking effect of the materials can give a false impression of control. As a result it is necessary to sample from several levels in the stump to determine whether the fungus is present. - SE

The effectiveness of borax for the control of *Fomes annosus* may not be due solely to sensitivity of the fungus to the chemical. In the laboratory the fungus has been grown on artificial media that contained this material at levels up to 60 times more concentrated than that reported to be fungitoxic. This suggests that control at lower concentrations is due to an interaction of factors that are not fully understood. - SE

The root infecting fungus, *Fomes annosus*, is capable of remaining alive in heavily resined roots for up to 50 years. Because of this longevity it poses a threat to future forestation of infection centers for that period of time. - PSW

Forest managers have expressed concern about the potential hazard of planting trees where *Fomes annosus* has caused damage. Studies in the Southeast suggest that previous infection may not be an important consideration when regenerating these sites. Losses on some of these areas have been so low that it has not been possible to detect any variation in susceptibility among several species of pine being tested. Observations will be continued, however, until these plantations reach commercial age so as to provide better information on the annosus hazard. - SE

Fresh loblolly pine stumps are highly susceptible to infection by *Fomes annosus* for up to 12 days after the tree is felled. After that time competition from another fungus limits further infection. This information is comparable to that from other areas where it has been shown that fresh stump surfaces are most susceptible to infection. - SE

Sand pine has been added to the list of trees that are susceptible to attack by *Fomes annosus*. Apparently infection took place through root contact between sand pine and infected longleaf pine roots. - SE

Spores of Fomes annosus survived up to 10 months in forest soils. Periodic sampling of infested and noninfested areas in a loblolly pine plantation indicated that spores were present in both areas but did not tend to accumulate in the soil. - SO

2. Poria weirii root rot. Encouraging alder to grow in association with conifers promises to be a useful silvicultural tool for minimizing the impact of Poria root rot. The fungus survives less well under pure stands of red alder or alder-conifer mixtures than under pure conifer stands. One explanation for this difference may be that the soil around the roots of alder differs from that of conifers both in kinds of mycorrhizal fungi present as well as kinds and numbers of other soil organisms. Of particular interest in this regard are species of Streptomyces, possible antagonists of root rot fungi, which are more prevalent in the presence of alder. - PNW

Fungitoxic materials produced from the oxidizing of phenolic compounds are believed to give alder its resistance to attack by Poria weirii. These materials are believed to prevent root penetration by the fungus. Douglas-fir, which incurs heavy root rot damage by P. weirii does not contain these phenolic compounds and therefore lacks such a defense mechanism. - PNW

Poria weirii suffers a competitive disadvantage in soils with a high nitrate content because of an inability to assimilate nitrate nitrogen. Lack of an enzyme commonly produced by some other fungi prevents assimilation. This may explain why the fungus survives less well in areas where alder is found because the soil in those areas is enriched by nitrate-nitrogen through production from nitrogen-fixing root nodules and leachate from leaves. - PNW

3. Other root diseases. A contract research study with Oregon State University has demonstrated that substances in the foliage of native shrubs and ponderosa pine stimulate growth of the Armillaria root rot fungus. These substances, when leached into the soil, could induce the fungus to grow from an infected tree to a healthy tree. This is one possibility that must be considered in the development of procedures to control the disease. - PNW

The cell walls of pine and Douglas-fir are resistant to direct attack by Verticicladiella wagenerii. This seems to be due to the inability of the fungus to use cellulose as a carbon source. When glucose, starch, or cellobiose are present the fungus grows well. - PSW

In Tennessee and Alabama a fungus has caused root rot, defoliation, and dieback of black walnut seedlings. This was identified as a species of Cylindrocladium, a fungus that has caused damage to nursery grown seedlings of several kinds. It was determined to be a different fungus from one that has caused a similar disease on yellow poplar. - SO

Six species of Pythium isolated from soil in forest nurseries in the Southeast caused mortality of shortleaf, slash, and loblolly pine seedlings. Surviving seedlings had restricted root and shoot systems. On poor sites this limited root development could result in the development of symptoms similar to those of littleleaf disease. - SE

Incorporation of pine litter, bark, or sawdust into forest nursery soil at the rate of 10 tons per acre resulted in a pronounced reduction of root diseases on ponderosa pine seedlings. - PNW

4. Mycorrhizae. Applications of soil fungicides and nematicides to the soil around pecan trees in south Georgia resulted in a marked improvement in foliage color and general vigor. Since the populations of root pathogens were not reduced the improvement was attributed to higher levels of mycorrhizal formation. The fungus, Scleroderma bovista, was the most common mycorrhizal fungus on these trees. - SE

Successful establishment and development of tree seedlings in soils low in nutrients depends upon the presence of fungi growing in association with the root systems. The suggestion has been made that this is due to an increase in absorbing surface or to some form of disease protection afforded the roots by these fungi. Certain of the fungi that are associated with root systems of southern pines produce antibiotics which may protect them against other fungi. The wide variety of different fungi inhibited by these materials suggests that they may be an important source of new and different antibiotics for possible use in agriculture and medicine. - SE

Fumigation of nursery beds with methyl bromide improved sweetgum growth by reducing the population of soil-inhabiting pathogens. Populations of mycorrhizal fungi also were reduced by this treatment. However, sufficient numbers of these fungi survived to permit rapid mycorrhizal development.-SO

Mycorrhizal fungi of sweetgum were not eliminated by shallow-water impoundment of winter rains on a forest area in the South. One result was a 50 percent increase in timber growth. Another result has been the encouragement of landowners to utilize their hardwood stands for water-fowl habitat. - SO

Only a limited number of mycorrhizal investigations of hardwood forest trees have been made. Recent investigations have shown that most oaks and pecan have ectotrophic mycorrhizae while elm, ash, yellow poplar, sweetgum, dogwood, sassafras, hackberry, sycamore, have endotrophic mycorrhizae. - SO

In forest nurseries, fertilizers are used to encourage good growth of seedlings but over-fertilization often produces stock with poor mycorrhizal development. Studies in India on the effect of different levels of N, P and K on mycorrhizal formation on chir pine may provide a basis for optimum fertilizer dosages for both mycorrhizae and host plants. - WO

Study of the physiology of both the higher and lower plant partner in the mycorrhizal relationship is important to understand symbiosis. The use of sugars by two isolates of Cenococcum graniforme was examined chromatographically at Dehra Dun, India. Such study helps in determining factors that influence the mycorrhizal association and in isolating and growing the fungus in culture. - WO

The morphological and anatomical features of mycorrhiza of blue pine (Pinus wallichiana), spruce (Picea smithiana) and deodar (Cedrus deodara) from different localities in the western Himalayas have been studied and described. These three conifers possess a wide spectrum of fungi with which the hosts may enter into mycorrhizal association and many are of worldwide distribution. - WO

5. Nematodes. Fungus feeding nematodes did not survive in sterile soil when tree roots were present but they did survive in non-sterile soil both when tree roots were present and absent. In non-sterile soil they apparently were supported by fungi. The same nematode species did well when tested against 26 known or suspected mycorrhizal fungi from New Mexico. Tests suggest that this nematode may be involved in the control of some root rot fungi. - RM

A geographical tabulation has been developed to show new plant-parasitic nematode associations with southern forest hardwoods and conifers other than pines. Several new nematode-tree associations are reported. This report is the result of a general nematode survey begun at the Southeastern Station in 1961. - SE

C. Stem diseases

1. Native rusts of conifers. Lodgepole pine is not seriously threatened by comandra rust even though mass infection does occur and once established damage continues for many years. Although large amounts of inoculum normally are present on the alternate host, unfavorable summer and early autumn weather usually prevents infection of pine. Extensive outbreaks probably occur only when large warm frontal rains invade and remain in the region for several days during the summer. Fortunately, this seldom happens in the Rocky Mountain states. When infection does occur the damage can be minimized by salvage logging and improvement cuttings. Disease intensity in future crop trees may be reduced by habitat manipulations that reduce the abundance of comandra plants. - INT

Comandra rust may prove to be more damaging in the South than in the more arid Western United States. Commercially important loblolly and shortleaf pines are heavily damaged when planted on sites where the alternate host occurs. In certain areas of eastern Tennessee, it has already caused land managers to stop planting loblolly pines. - SE

Western gall rust is caused by an unusual fungus that can reinfest pine without an alternate host whereas other closely related members of the Cronartium coleosporioides complex cannot. Aeciospores of this fungus produce uninucleate germ tubes while the others produce germ tubes that are binucleate. By understanding the life cycles of these damaging pathogens, progress can be made toward improved recommendations for sound silvicultural control. - INT

Infection of jack pine seedlings by stem rusts was not reduced by treatment with phytoactin, cycloheximide, methyl hydrazone, semicarbazone, or nickel sulfate. Treatment did delay sweetfern rust symptom development. Bioassays made 1 year after treatment showed no antibiotic activity remaining in treated seedlings. Some of the chemicals were phytotoxic. - NC

For the first time both eastern and western gall rust were found together on the same tree. This occurred on jack pine in northern Minnesota in an area where eastern gall rust is rare. It was not possible to distinguish between these two types of galls morphologically. - NC

There are three forms of the pine needle rust fungus, Coleosporium asterum in the Lake States. One of these which infects red and jack pines has goldenrod as an alternate host. Pine hosts are unknown for the other two forms that have asters as alternate hosts. - NC

The rust fungus Gymnosporangium cupressi has been demonstrated to have a life cycle based on alternation between cypress and serviceberry. It may be possible now to separate this little known fungus into varieties. - INT

2. White pine blister rust. Biological assays have provided considerable information on the absorption. Translocation and persistence of cycloheximide (Acti-dione) in white pine. Differences were found between species in concentration and retention of this material in the various tissues. Such differences could be important to the development and use of an effective antibiotic for blister rust control. - INT

A new technique has been developed at the Intermountain Station for testing blister rust resistant candidate trees. This method costs less than one-third as much as the previously used method. Because of a large potential number of trees to be tested considerable savings are expected to result. - INT

It has been confirmed that resistance to blister rust in western white pine is a highly heritable trait. This suggests that breeding programs already underway will be successful in producing pines resistant to the disease. In addition it has been found that early positive identification can now be made of hybrid seedlings. Formerly verification of hybrids was often delayed for many years. This new technique may become a potent force in hastening the incorporation of highly valuable resistance factors into white pine. - INT

Some characteristics of the white pine blister rust fungus have been studied in western white pine tissue cultures at the Intermountain Station. This was done to provide a means of identifying the fungus when it is present in these cultures. Success is dependent upon finding structures that are also found in rust infected tissues in nature. - INT

Infection by the white pine blister rust fungus may affect the distribution of chemical elements in the host tree. It is believed that some important elements are tied up in certain locations and that the movement of nonessential elements is altered. This may explain the influence of infection on chemicals introduced to control the disease. - INT

The antibiotics cycloheximide and phytoactin have been shown to be inhibitory to *Tuberculina maxima*, a parasitic fungus that is a beneficial in the control of white pine blister rust. Because of this fact past efforts to control the disease through direct antibiotic treatment may have been detrimental rather than just ineffective. This illustrates a need for knowledge of the effects of a pesticide on organisms other than the intended target. Future attempts at chemical control of blister rust should include an evaluation of the impact of the chemical on agents of biological control. - INT

In an effort to control blister rust on eastern white pine seedlings the antibiotics cycloheximide and phytoactin were applied as root dips, root slurries, and foliar drenches. None of the treatment tested were effective in controlling the disease. - NC

In the Pacific Northwest antibiotic materials tested against white pine blister rust on nursery grown sugar pine have been either phytotoxic or ineffective in controlling the disease. These materials were applied as foliage sprays, soil drenches and root soaks. Nickel salts have shown some promise for controlling infection. - PNW

Attempts to breed pines that are resistant to blister rust involve collecting pollen from widely separated areas. Now it has been shown that deep-freeze-stored pollen is satisfactory for use in these studies. This means that pollen collection travel and extraction work can be reduced. - INT

3. Fusiform rust. Both secondary and tertiary basidiospores of the fusiform rust fungus have infected pine in tests. Production of these spores greatly increases the infective potential of this fungus since each ensuing generation may again have the opportunity to reach and infect the pine alternate host. This knowledge greatly strengthens the concept that indirect germination is a significant stage in the life cycle of the fungus. - SE

A new technique has been developed for distinguishing between fusiform rust and eastern gall rust. This distinction is based upon the type of reaction that results when the spores of these rusts are inoculated to black oak. Because the range of these two closely related rust fungi overlap it has been difficult to identify individual infections. This is a particular problem when trying to develop disease resistant pines. Use of this technique will make it possible to identify the rust inoculum used to screen pine progeny for rust resistance. - SE

Work at the Southeastern Station suggests that most fusiform rust infections probably occur directly through succulent young stem or branch tissue. Previously it had been thought that the fungus could only become established through needles. It has been shown that needle infection is not necessarily followed by stem gall development. - SE

Weather conditions favorable to infection by fusiform rust are produced in the Gulf States by high-pressure systems off the Southeast coast. These systems cause maritime tropical air to move over the area. Charts to predict rust hazard under varying weather conditions are being prepared. It is now possible to predict 5 days in advance, weather conditions which favor rust infection of pines. Also, new instruments and procedures have been developed to permit simultaneous recording of temperature and humidity at several widely spaced locations. These developments should make it possible to minimize nursery losses at the least possible cost by concentrating control efforts to those periods when the infection potential is high. - SO

Information on the development of the fusiform rust fungus in oak leaves has been obtained at the Southern Station. Penetration, growth within the leaf, and development of reproductive stages were identified. - SO

Infection of pine by the fusiform rust fungus is related to number of spores available, length of time that relative humidity is at or above 97 percent and the number of hours that spores are present before 0700 hours. This information will aid in helping to predict rust hazard periods and should make rust control activities more effective. - SO

Pathogenic races of the fusiform rust fungus have been found at the Southern Station. While not unexpected this is the first report of a racial difference with this rust. Breeding pine for resistance to the disease may be complicated as a result. - SO

4. Canker diseases. Poplar cankers have been found in Ohio and Iowa with characteristics that are similar to those of a poplar canker in Europe. While bacteria have been isolated from these cankers, inoculations have not been successful. Bacterial ooze has never been observed associated with the American poplar cankers so the identity of this disease is still questionable. NE

A variation in susceptibility to hypoxylon canker has been demonstrated in a natural population of quaking aspen. While the genetic basis for this variation is unknown, it may result from morphological differences between genotypes that enable one clone to remain relatively disease-free while another clone without the same traits becomes more heavily infected. A further comparison of individual clones will be necessary to identify the factors associated with resistance to infection. - NC

Isolates of the hypoxylon canker fungus did not cause infection when introduced to host trees other than the species from which they were isolated.

This study involved collections from alder, aspen, and willow. The characteristics of the fruiting structures were not sufficiently different to justify regarding them as separate species. - SE

It has been demonstrated that Ceratocystis fimbriata causes a "nectria-like" canker on aspen in the Rocky Mountain area. The fungus can be transmitted by insects, several species of which were found to carry spores on their bodies. Infections often originate at trunk wounds, a place insects could be expected to frequent. - RM

5. Dwarf mistletoes. Infection of red firs by dwarf mistletoe is closely correlated to tree height and crown size. Trees one meter or less in height are nearly free of infection. Above one meter, both the percentage of trees infected and the intensity of infection increase with height. - PSW

The canker-producing fungus, Cytospora abietis, is considered a possible biological control agent for dwarf mistletoe. The amount of infection was found to be the same in different climatic and geographical zones in California. Older dwarf mistletoe infections may be more subject to attack by the fungus than younger infections. - PSW.

Dwarf mistletoe affects the physical properties of infected ponderosa pine wood. Moisture content is lowered and the specific gravity below an infection site is less than at or above the point of infection. This decrease in wood quality when added to reduced growth is further reason for attempting to control the disease. - PNW

Efforts to eradicate dwarf mistletoe from moderately to severely infected areas of ponderosa pine by annually cutting and pruning infected trees have not been successful. Latent infections are still developing 10 years after these control efforts were initiated. It is clear that additional control methods need to be developed for use in areas of moderate to high levels of infection. - PNW

Chromosomal and flowering characteristics of all dwarf mistletoes in the United States have been identified. Several morphological characters that are closely correlated with the various flowering groups in this genus represent a natural basis for developing a below-genus classification. - RM

Most dwarf mistletoe infections on lodgepole pine caused by Arceuthobium americanum produce shoots in the third or fourth year after infection becomes established. Abundant fruiting begins in the sixth year. On the basis of these findings it is recommended that sanitation projects for control of this disease include a recleaning 3 years after the initial operation. - RM

Prevalence of dwarf mistletoe is apparently related to topography. At the Rocky Mountain Station ponderosa pine stands on steep slopes were found to have much less infection than those on gentle slopes. This information will be helpful in rating areas for disease hazard and also for the development of control measures. - RM

6. Discoloration and decay. Recent work at Gulfport, Mississippi has shown that water storage of southern pine provides some residual decay resistance to the sapwood. Unfortunately this resistance is lost under temperature conditions highly favorable to decay. Results of further studies to learn more about increasing disease resistance should have widespread interest in the wood utilization field. - SO

Knowledge is scant as to when and in what numbers spores of tree decay fungi are produced. At the Southern Station it has been learned that *Polyporus hispidus* sporulates during the late summer and early autumn. These results add to our understanding of the life cycles of rot fungi and may be of value in determining the timing of sanitation cuts. - SO

Three fungi were responsible for causing 80 percent of the board foot decay volume of white fir in southwestern Oregon. External indicators were found on most of the defective trees. This information will provide a means for better estimating defect in standing timber. - PNW

A yellow stringy butt rot that is usually associated with old fire scars has been identified in Colorado. The fungus which caused this rot, *Lentinellus montanus*, is considered to be one of the 10 most important decay fungi of Engelmann spruce. Although found on lodgepole pine its significance on that host is unknown. - RM

Practical methods for determining time of death and volume deteriorated in beetle-killed fir have been developed at the Pacific Northwest Station. Because felling breakage is positively correlated with tree size and time since death, it now will be possible to minimize some of these losses. - PNW

Increased decay resistance may be imparted to pine wood by treating with an alkaline either with or without heat. The extent to which alteration of the thiamine in the wood is involved in change of decay resistance has not been determined. If heat is not needed in the treatment the practical use of alkaline preservative treating will be greatly increased. - FPL

The standard white-rot fungus used for appraisals of natural decay resistance of hardwoods, *Polyporus versicolor*, proved seriously deficient in its capacity to decay many tropical hardwoods. The deficiency was traced to apparent inadequacies of moisture and nutrients in the culture environment. With correction of these features the tests will be resumed. - FPL

Inoculations have been made from fungi and bacteria in Douglas-fir chip piles in the West. A technique for rapid screening of biocides that might be used on stored chips has been perfected through measuring the amount of CO_2 evolved during microorganism attack on dip-treated chips. - FPL

A technique has been developed for studying the population of bacteria in fresh wood. Because they are suspected of causing wetwood and of being an important link in microorganism succession, it is important to know more about the population distribution of these organisms. - PNW

A rod-shaped gram negative bacterium is associated with a wetwood disease of cottonwood in the South. This condition does not kill the tree. However, it causes degrade or rejection of the logs for some purposes. - SO

D. Foliage diseases

1. Air pollution. Fumigation of white, jack, and red pine seedlings indicates a variation in sensitivity to two important air pollutants, sulfur dioxide and ozone. From field screening studies several seedlings have been selected which exhibited outstanding characteristics for use in evaluating air pollution. If these characteristics are confirmed through further testing, this material will be a valuable tool for future air pollution studies. SE

Atmospheric pollution injury predisposes ponderosa pine to bark beetle infestation. As severity of oxidant injury increases the incidence of infestation also increases. This is believed to be associated with reduced oleoresin exudation pressure, yield and rate of flow. - PSW

Prolonged exposure to aerial oxidants, mainly ozone, appears to be the primary cause of a southern California disease on ponderosa pine referred to as X-disease, chlorotic decline, or ozone needle mottle. - PNW

Oxidant air pollution injury on ponderosa pine has been detected through the use of color aerial photography in California. Future use of this technique for detecting damage will permit rapid estimates of injury over large areas. PSW

2. Fungus diseases of conifer foliage. The fir needle rust caused by Hyalopsora aspidiotus has been found on grand, Pacific silver, and subalpine firs. An improved description of its symptoms makes this disease easier to recognize in the field. Because the fungus parasitizes only older needles it is thought to be one of the least destructive of the fir needle rusts.-INT

Phomopsis blight is a serious nursery disease of several species of the cypress family. It is much less important in natural stands. Epidemics in the Great Plains have resulted in total losses in seedling and transplant beds and many nurseries no longer produce seedlings of susceptible species. Control measures involve weekly spray schedules. - RM

Cercospora blight of junipers has been found recently in Nebraska. The disease can kill trees within three years. Observations indicate that spread is more rapid in Rocky Mountain juniper than in eastern redcedar. Symptoms usually appear during August and intensify during September and October. - RM

Damage to exotic pines by Diplodia tip blight is intensifying in the central Great Plains. Pines over 30 years old have been so extensively damaged that the esthetic value of trees in many residential and park plantings has been destroyed. Young trees are less severely injured. Infection of older trees may be related to cone production because the fungus can exist as a saprophyte and produce abundant pycnidia on cones. - RM

The needle cast fungus, Rhizosphaera kalkhoffii, which is damaging to planted blue spruce in many parts of the world, has been found in native stands for the first time. It was found also on native Engelmann spruce, a new host for the fungus. Damage to spruce stands in Arizona is negligible and under normal conditions this disease is not expected to be a serious problem on either of these spruces. - RM

3. Other foliage disorders. Top-dying of yellow birch in Michigan and Wisconsin has been associated with very heavy seed production. Symptoms appeared the year following a heavy seed crop. There is evidence to indicate that past outbreaks of top-dying also may have been associated with fruiting. NC

The effects of defoliation on tree decline and on quantitative and qualitative changes in food reserve were traced over a three-year period. The changes brought about as a result of defoliation may explain the increased tendency for root rot fungi to attack previously defoliated trees. - NE

E. Systemic diseases

The second phase of a cooperative evaluation of oak wilt control program in Pennsylvania and West Virginia has been completed. The Pennsylvania program reduced oak wilt incidence on study plots by 70 percent but at a high cost in healthy trees destroyed. In West Virginia incidence was reduced by only 14 percent. Another phase of this study designed to measure the effect of control on long distance spread has recently been started. - NE

The seasonal history and habits of two species of oak bark beetles common in Missouri, Ohio, and West Virginia have been determined. It was learned that they make breeding attacks on wilt-infected trees after which the parent adults and progeny leave to feed on healthy oaks. From this it is apparent that these insects can serve as a vector of the oak wilt fungus in that area. NE

Vegetative growth may be responsible for the upward spread of the oak wilt fungus in a newly infected tree. In a stand at the Delaware, Ohio, Laboratory, the fungus could not be isolated from vascular fluids but as time after inoculation increased the pathogen was isolated from woody tissue progressively higher on the stem. It is thought that water deficit may be important in symptom development. - NE

A toxin produced in culture by the oak wilt fungus has caused wilting on oak seedlings similar to that associated with the oak wilt disease. The toxin is a high molecular weight mannose polymer. While it remains to be shown that this toxin is produced in wilt-diseased oak, it meets the necessary criteria to be important in symptom development in the oak wilt disease. - NE

F. Biology and taxonomy of forest fungi

At the Beltsville Forest Disease Laboratory 204 fungal cultures were received for identification during the year. These represent both stains and decays of forest trees as well as wood in use. In addition, 285 isolates of fungi were shipped to various requesting agencies and 412 cultures, including 22 species new to the collections, were added to the Reference Culture Collections. The culture collections now number 11,569 isolates (representing 1,164 named species). - WO

G. Miscellaneous disease studies

Conifers are associated with the greatest number of failures in hazardous trees on recreational sites west of the Mississippi. Lodgepole pine is the most important in this regard with ponderosa pine as the second most damaging species. The number of failures in California increased greatly during the 1968-69 winter. - PSW

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FOREST PRODUCTS AND ENGINEERING RESEARCH

FOREST PRODUCTS UTILIZATION RESEARCH

Problems and Objectives

Some of our timber resources are now in short supply. Such shortages are expected to become more severe with increasing demand. Maximum benefit from our forest resource is not being realized. The forest products industry is facing a continuing decline in the quality of available timber supplies. At the same time, small and poor-quality trees, certain species, waste paper, and bark are underutilized. There is excessive waste in harvesting and processing. Stumps, branches, and tops are ordinarily not used. Frequent pollution of air and water results from disposal of mill effluents and waste residues. Adequate knowledge about wood and timber qualities and characteristics is lacking. More efficient structural applications are hindered by lack of suitable evaluation systems and engineering information.

Major objectives of the research are to:

1. Utilize the complete tree, including stumps, tops, and branches.
2. Increase utilization of low-quality trees, under-used species, residues, and waste paper.
3. Reduce air and water pollution associated with wood utilization.
4. Characterize and improve wood and timber quality and develop systems to allocate raw materials to highest value use.
5. Develop improved wood products and wood fiber products.
6. Obtain improved resource utilization through a better understanding of the pulping and chemistry of wood.
7. Develop the engineering concepts and information required for the more efficient use of wood in structural applications with emphasis on low-cost house construction.

Progress

A. Wood and Timber Quality

Complete plantlets grown from undifferentiated cambial tissue. A significant biological breakthrough was achieved when undifferentiated tissue isolated from the cambium of an aspen tree and grown in culture formed organs when supplied with specific growth hormones. Complete plantlets, which are genetically identical to the parent tree, have developed from these organs. Determination of all the essential nutrients and the amounts necessary for maintaining cambial tissue led to this achievement and a complete synthetic nutrient media is now available for similar experiments. Differentiation into tailored trees of particular wood structure may now be possible. - FPL

Thinning young timber stands improves wood quality. Despite the increase in investment, thinning and pruning forest crops can increase the average yearly net return per acre by producing wood of superior quality in addition to accelerating volume growth. Wood produced 4 years after heavy thinning and pruning of a stand of loblolly pine showed a significant increase in both specific gravity and percentage of latewood. Thus, thinned and pruned stands yield more wood, stronger wood, and a greater percentage of clear wood. - FPL

Utilization of southern pine reviewed. The current body of information applicable to southern pine utilization was the subject of a symposium, "Utilization of Southern Pines," hosted by the Southern Station at Alexandria, La. The entire field of southern pine wood technology was brought up to date and consolidated in the program to familiarize conferees with the characterization of wood and bark as an industrial raw material, conversion processes, and major products. All 10 species of southern pines were considered. - SO

Soil properties and site contribute to color of black walnut. This investigation provides the first information for any species on wood color differences, as measured with a spectrophotometer, between trees at specified locations. Larger differences were found between black walnut trees in heartwood luminance (lightness) than in dominant wavelength or purity, and such differences were related to geographic location. Results also show that soil properties are associated with wood color. These findings suggest the possibility of controlling wood color by manipulating soil properties. - FPL

A classroom manual to demonstrate wood properties. A manual, "Classroom Demonstrations of Wood Properties," was prepared to provide school teachers with outlined simple demonstrations that illustrate how wood behaves. The selected demonstrations deal with the more important properties of wood and how these properties relate to the cellular structure. They are easy to perform and require little in the way of special apparatus. This manual is not intended to provide a basis for a full course of study but be an educational aid in presenting facts about wood, in clarifying misconceptions, and in avoiding misuses of wood. - FPL

Physical properties of barks determined. An investigation of seven northern timber species shows that bark properties, like those of wood, are a species characteristic and that the properties differ between the inner and outer bark zone. The specific gravity of the barks was found to differ from that of the wood specific gravity and these differences assume many patterns. These data strengthen the technological tools required for more complete utilization of the whole tree, and can be applied to the development of systems for separating bark and wood. - NC

A useful manual of converting factors compiled for southern pine. Many different units of measurement are traditionally used in the wood industry for describing the standing tree, the log, the bolt, or the many other raw material types and, finally, the products. A new manual, "Converting Factors for Southern Pine Products," brings together all measurements now in use and provides factors to readily convert from one unit of measure to another. - SO

Specific gravity variation in southern pines. Knowledge of the variation in specific gravity is useful to the wood industries in their selection of woods most suitable for a given product. Except for shortleaf pine, which does not significantly vary geographically, six other southern pine species studied show increasing specific gravity from north to south and west to east. - SE

B. Wood Processing and Wood Products

Slicing wood into lumber saves wood. Research with a special experimental cutting machine is now producing the engineering and processing information needed to design a prototype commercial slicing machine. Slicing should enable production of lumber as thick as 1 inch without loss as sawdust, without planing, and with greater accuracy. The increase in usable lumber due to eliminating sawdust is estimated to be worth more than $150 million annually. - FPL

Longer life for timbers. Methods have been developed for preventing the splitting and checking that often occurs in drying of timbers and for repairing them after checking has taken place. Splits and checks reduce load-bearing capacity, detract from appearance, and trap water that may lead to decay. This often requires that timbers be replaced long before their expected usefulness has been realized. Millions of dollars are lost annually in such replacements, and the Nation's timber resources are unnecessarily depleted. Checks can be prevented by bonding a single sheet of veneer with a waterproof glue to the upper surface of a timber. This method will be especially useful for railroad ties and bridge stringers. The repair procedure, particularly useful for nonreplaceable structural beams, involves filling the openings with a specially formulated gap-filling adhesive material. This will improve appearance and performance of the timbers. - FPL

New protective finish for weather-exposed wood. Better protection against weathering results from newly developed finishing systems for wood. A natural finish, which combats micro-organisms and screens out ultraviolet light, is inexpensive, easily applied, and long lasting. It is a penetrating type of finish and will probably find widest use on farm buildings, fences, summer cottages, and other structures where rough or low-grade lumber and plywood are commonly used. Special coatings can be applied over the new stable finish on smooth surfaces to give a varnish-like appearance. - FPL

Systems approach to drying hardwoods improves yields and lowers costs. Traditionally, green lumber is kiln dried directly after sawing. It was found that if the green lumber is surfaced, cut to length, graded, and the defects removed before kiln drying, economies result through shorter drying times, less degrade (checking, splitting, warping), more efficient use of kiln space, and opportunities for automatic stacking and handling in unitized loads. The systems approach is particularly useful in drying lumber as cuttings. The techniques, developed for drying red oak and beech, may also be applicable to drying other hardwood species of commercial interest, with savings of millions of dollars annually. - NE

Marketable product from ponderosa pine bark residue. The addition of nitrogen with subsequent aeration accelerated the decomposition of ponderosa pine bark for use as a beneficial soil amendment. This provides a sounder economic base for a composting industry in the Black Hills, and offers a means of eliminating air pollution, since the current and costly practice of bark disposal is by burning. The annual production of bark from the sawmills in the Black Hills is estimated to be 20,000 tons. - RM

Sawing method reduces warp in lodgepole pine studs. Results from sawing 700 lodgepole pine logs show a new sawing method substantially better than the conventional method to yield warp-free, 2- by 4-inch studs. Studs from butt logs are more prone to crook and bow and less prone to twist than studs from upper logs. Specific recommendations are made regarding log positioning on the sawmill carriage and sawing pattern. - FPL

C. Wood Pulping and Wood Fiber Products

Cost of hardwood pulp-bleach facility reduced. Extensive evaluation of a simplified bleach process has demonstrated that, for some grades of hardwood pulp, the number of bleach stages can be reduced from the usual 5 to 8 down to 3, with an accompanying reduction in the intensity of the color of the effluent. At $300,000 per stage, this substantially cuts the initial cost of a pulp-bleach facility. Since pulps of maximum brightness cannot be produced by this process, it could be of particular value in developing areas outside of the U.S. and in other locations where there is a good demand for hardwood pulp of lower brightness and where investment capital is limited. - FPL

New method of applying additives to paper reduces pollution. In paper production, applying starch and resin directly to the wet paper mat rather than to the original watery pulp slurry eliminates the waste of chemicals and the resultant water pollution. When applied directly, the additives also retain their effectiveness in improving the water resistance and surface properties of the paper and there is a resulting unit cost reduction. - FPL

D. Wood Chemistry

Study of chemicals in jack pine bark completed. More than 100 chemical compounds have been isolated from jack pine bark and identified. They include fats, waxes, resins, and sterols. Nineteen of the chemicals found are new natural products. This comprehensive study of pine bark chemistry will provide a basis for evaluating the feasibility of bark chemical utilization and will contribute to a better understanding of the disease resistance, insect resistance, and chemistry of wood and of the biosynthesis of natural products. - FPL

Biological path to decomposition of lignin clarified. Lignin is degraded by fungi through the enzymatic oxidation of phenolic groupings causing depolymerization and humic acid formation. This new information helps illuminate the role of lignin in the carbon cycle in nature and its function in soil formation and improvement. A more complete understanding of this mechanism can have a bearing on the utilization of wood and bark as soil conditioners, mulches, and animal bedding and on the possibilities for the pulping of wood with enzymes. - FPL

Continuous densifying process hardens wood surfaces. A procedure for densifying the surface of wood has been cooperatively developed and evaluated. In the process, high temperature and pressure are applied to the wood piece through a continuous feed press. Abrasion resistance is greatly increased and the natural wood appearance gains a finished look. Enhanced wear resistance and aesthetic qualities attainable by this procedure can significantly improve wood products such as furniture. - FPL

E. Wood Engineering

A new sampling scheme for evaluating the mechanical properties of wood. A new, direct, and random sampling scheme providing greater precision in estimating the mechanical properties of wood has been developed and tested. The scheme enables a confidence statement to be made with respect to the statistically important 5 percent exclusion limit of technical structural properties. This has not been possible with previously employed methods. The new, simpler, and less costly sampling system will be applied to the determination of mechanical property values of lesser used tree species that are gaining in commercial importance. The method provides a statistical standard of excellence along with the needed mechanical property estimates. - FPL

Cost reduction possible with fabricated hardboard beams. Built-up beams and other structural components are becoming more important as the cost of wood increases and supplies become more critical. A study on the design of beams incorporating a hardboard web has developed information valuable to architects, engineers, and house builders relative to structural applications of hardboard and engineering factors that must be considered. Design values derived for 1/4-inch-thick tempered hardboard were used to design a

34-foot-long, 16-inch-high hardboard web I-beam. Tests on prototypes over a 30-foot span show that I-beams with hardboard webs utilize 30 to 40 percent less wood than conventional solid or laminated wood members without any sacrifice in strength. - FPL

Glued laminated wood panels make superior quality bridge decks. Glued laminated bridge-deck systems properly treated with oilborne preservatives will provide greatly improved service life over conventional nail-laminated systems. The success of wood bridge decking depends on the imperviousness of the deck surface. Because of the looseness of the nail-laminated deck system, many seal coatings have not been successful. The glued laminated panel deck has the stiffness necessary to allow effective use of bituminous mats as a wearing course and sealant base on wood bridges, thereby improving performance and reducing maintenance costs. - FPL

Improved blocking and bracing design in rail cars saves money. A large portion of the $150 million the railroads pay annually to satisfy claims for damage incurred in freight shipments is due to inadequate fastening of wood blocking and bracing in rail cars. Existing design criteria, developed for structural applications, are misleading because fastener systems for railway blocking and bracing undergo dynamic shock loading. Design criteria, based on resistance of nailed cleats to realistic lateral shock forces, have been developed to aid in proper design and application of blocking and bracing to reduce losses and improve low-quality timber performance. - FPL

F. Wood in House Construction

More efficient use of wood in low-cost houses for rural America. Four house plans, which range from a small two-bedroom design to a five-bedroom home, have been developed. Highlighting up-to-date wood construction principles, the plans feature most efficient use of wood at minimum cost. Detailed plans, complete with specifications and bills of material, will be made available nationally through the USDA-State Cooperative Plan Service, primarily from extension agricultural engineers located at state universities. - FPL

Designs have also been developed for three other low-cost homes of conventional type and three additional ones that provide maximum space utilization and livability while featuring unconventional building techniques and appearance. Experimental features, based on previous research findings, provide for most efficient use of wood. Prototypes of round, tubular, and hillside duplex houses that emphasize pole foundation and structural systems are under construction by private builders. These are being studied during construction and occupancy. - SE

As a further aid to home builders, a publication "Low-Cost Wood Homes for Rural America--Construction Manual" is now available as Agriculture Handbook No. 364. Designed especially for the small home builder and the do-it-yourself public, the manual has more than 120 figures and accompanying discussions covering important details needed for building low-cost houses of wood. Emphasis is given to use of the latest construction techniques and locally obtainable materials. - FPL

Better protection of wood in service. Lower cost and improved fire-retardant treatments are needed for use in building construction to improve safety, reduce replacement requirements, and conform to low-level flammability specifications in buildings. Inexpensive ammonium polyphosphate liquid fertilizers produced by the Tennessee Valley Authority have now been shown to be effective fire retardants for wood. They can be used in place of ammonium phosphate salts, now commonly used, with a saving of 30-40 percent in chemical and treatment costs. Southern pine treated with the liquid fertilizers met building-code, fire-rating, and other requirements. - FPL

Collaborating scientists in the U.S. and Canada have found that wooden bait blocks with *Lenzites trabea* decay attract termites even though dip-treated with a slow-acting poison. Termite foraging was abruptly suppressed when bait blocks, attached to stakes, were placed in the ground around buildings where termites were active. If this radically new method of combating termites proves capable of eliminating localized pockets of infestation and also prevents expansion of colonies, it is possible that the need for costly and dangerous forms of prevention and eradication, such as extensive soil poisoning, may be eliminated. The new method has potential for huge savings since the total termite damage in the United States is estimated at $250 million annually. - FPL

With the large number of housing starts anticipated for the next decade, interest is intensifying in the serviceability of wood foundations. While not a new use for wood, such application is a critical use in that the wood is required to simultaneously support the weight of the structure and to act as a retaining wall resisting the lateral pressure of the soil. An opportunity to evaluate a treated wood foundation was recently possible when an experimental house, nearly 30 years old, was moved to a new location. Only slight reduction in the mechanical properties of the southern pine planks and posts was indicated, and these were limited to a few areas where preservative treatment was omitted or erratic. The treated foundation gave excellent service and met its required use. - FPL

Wood and Timber Quality

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FOREST ENGINEERING RESEARCH

Problems and Objectives

About 1.6 billion dollars annually is required to harvest and transport the Nation's timber crop to primary processing plants, about 60% of the total cost of the raw material at the plant--a much higher percentage than for competing industries. An estimated 585 million cubic feet of annual allowable cut in the West is currently non-loggable with conventional systems. A large percentage of the standing timber harvested is left in the woods in the form of tops, timber culls and debris. Worker productivity is low; woods labor supply is dwindling; woods workers' accident rate is one of the highest in industry; all of which tend to depress rural forest economy. Many logging operations are incompatible and/or damaging to other forest values such as recreation, natural beauty, and water.

The major objectives of Forest Engineering Research are to develop new and improved engineering systems and to evaluate alternative ways to:

1. Reduce the cost, and impacts on other uses, of timber harvest and transport.
2. Obtain economic access to inoperable timber.
3. Mechanize--and automate--forestry operations.
4. Improve woods worker productivity and safety.
5. Develop economic removal systems for logging wastes.

Progress

A. Engineering Systems for Forestry Operations in Heavy Timber and Difficult Access Areas.

A publication was released on planning single span skylines which presents criteria for selecting areas suitable for skyline logging. Also shown are the steps that must be considered by the logging planner from preliminary cutting unit layout to the final location of skyline roads. - PNW

A skyline logging symposium at Corvallis, Oregon was conducted in cooperation with Oregon State University and University of Washington. Over 500 loggers, land managers, equipment manufacturers, forestry consultants, and research people attended the three-day session. Skyline logging was shown to be an explosive technology with prospects of great impacts on land management, as well as on training needs for engineers and foresters. - PNW

B. Transportation Systems and the Movement of Small and Medium-Sized Timber on Mountainous Terrain.

The development of hydraulic wood-chip pipeline transport that is nearing completion will have a significant effect on the cost of transporting low value forest products, especially from virgin areas in the West and Alaska. Benefits to watershed management in fragile soil areas will also accrue because of reduced road mileage. It is estimated that this method of transport could produce a savings of as much as $65 to $70 million annually. The potential benefits to watershed management cannot be measured adequately at present, but would be very significant. - INT

An engineering investigation of forest road failures in the deeply dissected, steep, erosive drainages at Zena Creek on the Payette National Forest in Idaho produced design criteria that should be very valuable for the design of more stable roads in this area of the Idaho Batholith in the future. Excessive structural failures of cut and fill slopes resulted in extensive damage to the watersheds and stream channels. - INT

In the Rocky Mountain area, a major portion of the high cost of logging is the skidding or yarding. A method of optimizing skidding or yarding using present equipment available to loggers has been developed. The method can be understood and used by the logger without special training and will help him find an optimum solution when the variables of stand density, slope, logs per 1,000 board feet, and skidding distance are known. - INT

C. Engineering Systems for Northern Hardwood Forests.

Quest for low-cost, high-quality wood chips has led to the development of chipping machines in which the principal cutting action is parallel to the longitudinal axis of the fibers. A recent study revealed that the parallel-type chipper consumes less energy than the conventional chipper. This, plus the light weight of the parallel-type chipper, makes it well suited for portable as well as mill operation. - NC

D. Engineering Systems for Appalachian Type Forestry.

High demand for wood products and woods labor problems dictate the need for more efficient and more easily handled equipment--including a lighter, more powerful portable power supply which is safe, simply operated, and economical. A general feasibility study of exotic fuel gas generators indicated the importance of four primary factors: physical, mechanical, safety, and economy. With present fuels, generators as known today are not feasible for portable logging tools but do show a potential for balloon inflation and fire-fighting tank pressurization. The results of this investigation will be of value in planning and conducting further research in this field. - NE

Replacement of skidder tires is a major logging cost. A model for estimating tire wear on Appalachian logging operations was developed from observations and tread measurements made at many operations. Factors evaluated were: number of days of machine operation; tire width and diameter; skid-road slope and location; board feet skidded; and horsepower to weight ratio. Regression analysis accounted for 66, 59, 48, and 51 percent of the wear of right front, right rear, left rear, and left front tires, respectively. Part of the unaccounted for variation can be attributed to operator and tire brand. Results can be used to obtain a more accurate estimate of production cost and to improve operations for more economy and efficiency. - NE

Loading of logs from landing to truck is one of the operations where more efficient and less arduous methods are needed. The loading cycle of a rubber-tired front-end loader was studied using a controlled experimental design at an actual woods operation with a muddy and uneven landing area. The moment-of-inertia of the log was the most significant variable affecting time required to pick it up. But when the log was placed on the truck, the interaction of moment-of-inertia and weight-per-board-foot was most important. For the total loading cycle, interaction of moment-of-inertia and distance traveled was significant in explaining variation in time expended. Techniques and procedures developed from this study will help loader operators cut loading time and reduce costs. - NE

Experiments using wheeled skidders to log hardwood on moderate and steep slopes were carried out. Time study information was plotted for the steep and moderate slope operations and should prove valuable for loggers in estimating and predicting productivity for their logging operations. Forces required to winch logs to the tractors under different conditions were recorded. This information should prove useful to skidder designers in improving equipment for loggers. - NE

E. Engineering Systems for Intensive Forest Management.

The theoretical feasibility of aerial seeding in rows with arbitrary 4 ft. wide beds spaced approximately 12 feet on center has been established. Limited experimentation has confirmed these findings but further development in several areas must take place before such a system becomes operational. A program of research leading to a successful operational system has been outlined. - SO

The theoretical feasibility of developing walking machines for use in gum naval stores harvesting has been determined. The operational philosophy on which the feasibility was based is that of providing mobility through automatically sequencing and coordinating the appendages. Operation control is achieved by regulating stride length and frequency as well as stride direction. Programmed motion appendage configurations of 2, 4, and 6 levers were evaluated. - SO

The effect of soil strength on the speed and pulling power of an articulated rubber-tire skidder was evaluated. Articulation was of no advantage for speed nor for pulling power in the range of soil strengths evaluated. One vehicle operating in heavy clay soil was evaluated. Soil strength measurements were made by cone penetrometer using methods developed by the U. S. Army Waterway Experiment Station. - SO

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FOREST ECONOMICS AND MARKETING RESEARCH
FOREST SURVEY

Problems and Objectives

The United States has some 510 million acres of commercial forest land which vary greatly in productivity and availability for industrial use. These forests also show widely divergent and rapidly changing trends in growth, depletion,and opportunities for industrial development. At the present time about $700 million is being spent annually on the protection, development, and management of forest lands for timber production. In addition, capital expenditures in the timber-based industries such as the lumber and wood products and paper and allied products industries amount to about $2 billion a year.

The general objectives of Forest Survey research are to:

1. Collect and compile up-to-date basic information relating to the present and prospective supply and demand situation for timber for individual States and for the Nation,
2. Make technical interpretations of data on timber inventories, growth, mortality, and timber use that will provide a sound basis for forest policy and program decisions on national, State, and local levels, and
3. Intensify the Survey to provide more localized information needed by public and private organizations in carrying out forestry programs, particularly programs concerned with forest industrial development in rural areas and regional planning.

Progress

A. Forest Inventory

1. Field surveys conducted in 11 States. During the past year the equivalent of approximately 47 million acres of commercial forest land was inventoried. Field surveys were conducted in Alaska, Arkansas, California, Florida, Maine, Nevada, New York, Oregon, South Carolina, Washington, and Wisconsin. Reports appraising the forest situation were issued for 8 States or portions of States.

Resurveys of States are being made at intervals of 10 to 15 years. Because of rapid changes in timber cut and growth, more frequent coverage is needed to provide guides for forestry and rural development programs. - WO

2. Forest Survey of Humboldt County, California completed. After 100 years of harvesting old-growth stands in the county, the harvest of young growth stands is beginning. The harvest of old growth will, for all practical

purposes, come to end within 20 years. However, redwood will continue to be a major part of the timber harvest as cutting shifts over to the young-growth forests. Forest lands in public and forest industry ownership will be the major source of future harvests. The large area of conifer sites which now support hardwood species poses a problem for the future since the hardwoods are of low quality and are not producing the volume these sites are capable of. Eventually such lands often revert to softwood. However, the natural progression is slow, effectively removing these lands from production for a long time. Thus, if present cutting rates continue, the county's annual cut can only be maintained for about 15 years, followed by an abrupt decrease to levels of allowable cut on public lands and sustainable levels of cut on private lands. - PNW

3. Kansas forests primarily hardwood. A recent survey of the forest resources of Kansas showed the 1.2 million acres of commercial forest land in the State support 490 million cubic feet of growing stock, including 1,809 million board feet of sawtimber. Over half the growing stock volume is in trees larger than 15 inches in diameter. Cottonwood and elm are the most prevalent species. Net growth of growing stock in 1964 exceeded cut by about 4 times. Black walnut, bur oak, soft maples, and cottonwood made up over half the cut. Allowing for overcutting in certain species and quality classes, and changes in land use, it appears growing stock could easily be increased 75 percent over the 1964 level. - NC

4. Forest resource conditions in East Oklahoma changed appreciably between 1956 and 1966. As part of a continuing program to evaluate the timber resource situation in the Midsouth, a third survey of the timber resources of East Oklahoma was completed. Growth of softwood timber was high enough between 1956 and 1966 to support industry's needs for timber and at the same time permit a sizable buildup in pine volume--a 31 percent increase. The outlook is for further gains in pine resources. The hardwood situation is much less encouraging. There is 7 percent less volume now than a decade ago and without more intensive management, prospects appear dim for any substantial hardwood timber supply improvement. - SO

5. Forest Survey of South Dakota completed. A recent survey of the forest resources of South Dakota showed that the State had 1.5 million acres of commercial forests. Ponderosa pine type, mostly in the far western part of the State, occupies 87 percent of the commercial area. Inventory of all species amounts to 1,058 million cubic feet, including 3,716 million board feet of sawtimber. Net annual growth amounts to 25 million cubic feet while removals from growing stock amount to 13 million cubic feet. Both growth and removals are expected to continue to rise. - NC

6. Forest area and growing stock volume increasing in Vermont. The second forest survey of the forest resources of Vermont shows commercial forest land now totals 4.3 million acres--73 percent of the State, compared with 57 percent in 1948. Most of the State's commercial forest land--91 percent--is privately owned. Although the volume of growing stock totaled 3.7 billion cubic feet in 1966, compared to 3.4 billion cubic feet in 1948, this

increase failed to keep pace with the increase in forest area. Furthermore, the volume of sawtimber declined 1 billion board feet over the same period. Quality of the timber is generally poor with only about one-third of the sawtimber volume qualifying as standard lumber log grades 1 and 2. - NE

B. Timber Production

1. Over half the Nation's treated poles and piling come from the Midsouth. Virtually all the poles and piling produced in the South in 1967 was southern pine. Utility poles comprised three-fourths of the output, construction poles 6 percent, and piling 19 percent. Some 4 million softwood trees in the region are cut annually for poles and piling out of an estimated inventory of 430 million pine trees suitable for manufacture. - SO

2. The South's pulpwood industry again had a record-breaking year in 1967. A total of 33.6 million cords of wood were produced. This amounted to nearly 63 percent of the Nation's total. Significant gains were noted in the use of chips, whereas roundwood receipts at pulp mills showed a slight decrease for the first time in ten years. Southern pulpwood went to 92 mills in the 12 southern States and 8 mills outside of the South. With the addition of new mills and expansion of existing mills that occurred during 1967, the South's pulping capacity increased from 66,726 tons per day to 70,527 tons per day. In addition, 8 mills under construction will add 5,300 tons per day. - SO

3. Lake States pulpwood production drops slightly in 1967. The Lake States pulpwood harvest decreased to about 4 million cords from a record high of 4-1/2 million cords in 1966. Only Minnesota's 1967 pulpwood harvest was higher than the previous year. - NC

4. Northeast States pulpwood production continues to rise. Production of all forms of pulpwood in the Northeast climbed to over 6 million cords in 1967, a 5 percent increase over 1966. This increase was considerably below the 12 percent increase experienced between 1965 and 1966 and below the average annual increase of 7 percent experienced over the past 5 years. Production of pulpwood chips rose from 558 to 708 thousand cords in 1967, an increase of 27 percent over 1966. - NE

5. South pulpwood prices edge to record high. The pulp industry in the Midsouth paid about $229 million for pulpwood delivered to wood yards or mills. The average price for hardwood bolts was $15.19 per cord, up 15 cents from 1966. Pine bolts sold for $17.16 per cord, an increase of 29 cents. However, within the Midsouth some areas did not follow regional trends. - SO

6. Southeast pulpwood prices also edged up. Pulpwood prices paid in the Southeast followed a similar pattern. Pine bolts sold for $19.25 per cord, up 45 cents from 1966. Hardwood bolts sold for $15.55 per cord, an increase of 65 cents over 1966. - SE

7. Mississippi industrial roundwood harvest largest in a decade. Nearly 402 million cubic feet of industrial roundwood were harvested in 1966. Nearly three-fifths was softwood--mainly pine. Use of wood for pulpwood accounted for about one-half the total harvest; saw logs accounted for another 42 percent of the harvest. Of the 1,009 million board feet of saw logs harvested, 96 percent were processed within the State. - SO

C. Survey Techniques Research

1. Computer program developed for calculation of tree volumes with interior defect. NETVSL is a comprehensive and efficient computer program that calculates gross volume, net volume, surface area, and length of tree boles from stem measurements. These measurements can be obtained either from felled trees, or taken by a dendrometer from standing trees. Volume units include cubic feet and board feet (Scribner and/or International 1/4-inch log scale). Merchantable content is calculated from stump heights, log lengths, and top diameter limits. - INT

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FOREST ECONOMICS RESEARCH

Problems and Objectives

About $700 million is now spent annually by forest owners for timber production on forest lands. Substantial amounts also are being spent on programs to meet rapidly rising demands for recreation, water, wildlife, and other forest goods and services. Expenditures are increasing rapidly on industrial ownerships, especially in the South and Douglas-fir region, and on Forest Service and other federal lands. Major programs to accelerate management on National Forests also have recently been proposed to alleviate prospective shortages of timber supplies. There are major needs for economic analyses to guide these expenditures for timber and other resource management.

Improved information is needed on the costs and benefits of various rotation lengths, thinning schedules, and stocking levels so that owners may select the alternatives that best meet their goals. Data are likewise needed on costs and financial returns from planting nonstocked areas, conversion of low productivity forest types, and various timber stand improvement measures. Improved methods of planning multiple use management on forest lands are particularly needed on public lands. There is also a major need for information to improve public programs that assist farm and miscellaneous owners and to stimulate management practices on these lands.

The general objectives of Forest Economics research are to:

1. Develop economic guides for efficient management of timber stands, including optimum rotation ages, stocking levels, and investments in site preparation and timber stand improvement,

2. Determine size and mix of regional forestry programs that would most effectively and cheaply supply the Nation's future demands for timber and other forest products,

3. Provide guides for integrating and balancing multiple uses of forest land to meet expanding demands for timber, water, wildlife, recreation, and other forest goods and services, and

4. Identify the most effective programs for stimulating the millions of farm and miscellaneous private owners to follow productive management practices.

Progress

A. Economic Guides for Timber Management

1. Evaluation of timber production investments under uncertainty. A computer program has been written to calculate probability distributions of present worths or rates of returns of investments in timber production. Inputs

can include probabilistic estimates of future costs, prices, and yields. The program allows the analyst to explicitly consider uncertainties surrounding estimates of project costs and incomes and evaluate large numbers of investment alternatives. - NC

2. Scheduling allowable cut using either area or volume regulation. A computer program was developed to calculate allowable cut, using either area or volume regulation, at the beginning of each planning period within a rotation. The program enables the timber management planner to trace further allowable cut over time and to introduce growth and utilization expectations as program inputs for each planning period. - PNW

3. Dynamic programming to determine optimum levels of growing stock. Dynamic programming has been found to have analytic and computational advantages as a method of solving for optimal levels of growing stock. This technique is appropriate where growth and economic data indicate interdependence between growing stock levels at different periods. - PSW

4. Analyses of stand improvement and reforestation opportunities in Appalachian forests. Investment opportunities on National Forests in Appalachia were evaluated to indicate the kind of projects to favor in planning stand treatment programs. Among the projects evaluated, highest priority was indicated for stand improvement on good sites. Next best were stand improvement on medium sites and conversion of forest types where costs are low and yields high. - NE

5. Conversion surplus as a measure of value. A procedure has been developed for determining marginal trees or portions of trees for timber processors. The analysis compares pay-as-cut with lump-sum timber sales and indicates advantages of selling timber by the parcel rather than by the unit. Using the principles developed would encourage multi-product sales which reduce administrative costs and contribute to more economic timber utilization. - SO

6. Financial maturity in plantation management. Application of the financial maturity principle can determine when a pine plantation should be harvested. This study also analyzed problems associated with scarcity of land or capital and the connection with capital budgeting. - SO

7. Financial returns from white pine plantations. Data developed on financial returns from white pine plantations provides investors and forest managers a means for evaluating local investment opportunities for plantation establishment. - NE

B. Regional Forestry Programs

1. Competition among industries for southern pine timber. Plants in the lumber, pulp, and plywood industries face increasing competition. The pulp industry has some competitive advantages in that it can take wood from trees almost regardless of size, species, and quality, and including sawtimber

tops and cull trees. Coarse mill residues such as slabs, edgings, and end trim which are chipped,and even sawdust and planer-mill shavings, can be pulped. The plywood industry has the most stringent requirements in raw material while lumbermen must fit themselves between their two main competitors. Many lumbermen might carry the process of manufacture into laminates, furniture parts and trusses to raise product values. Even though competition seems certain to heighten, sawmill managers have certain opportunities for improving their competitive position. - SO

2. Importance of timber-based employment to the economic base of the Douglas-fir region. Degree of economic dependency upon timber industries was estimated for 15 subareas of the Douglas-fir region of Washington, Oregon, and California. Dependency, measured in terms of the percent of base employment accounted for by the timber-dependent industries, ranged from 6.2 percent for the Seattle economic area to 99.4 percent for the Roseburg area. Timber-dependent industries accounted for approximately 45 percent of the Douglas-fir region's economic base employment. - PNW

3. Potential growth of softwood plywood industry in South. The potential for softwood plywood to be produced from southern pine in competition with western species was estimated by linear programming. Impediments to industrial migration are apt to prevent the South from achieving a theoretical 56 percent of the Nation's output of plywood. However, a third of the Nation's plywood capacity could be located in the South by 1975. The analysis is based on the relative costs of logging and manufacturing plywood and lumber in the major forest areas as well as the costs of transporting these products to the Nation's markets. - SO

4. Economics of plywood production in the South. Transportation and other cost factors provide a price umbrella for southern plywood producers. Development of the industry so far has been in areas with the most favorable timber supplies, but as the industry expands it will have to adapt to more typical timber supply situations, including procurement of timber from small ownerships. Average log diameter is apt to be about 12 inches, and the veneer suitable mainly for sheathing grades of plywood. Opportunities for modifying output in response to market changes may encourage prospective firms to combine plywood and lumber manufacture. - SO

C. Economics of Multiple Use Decisions

1. Status of pilot watershed studies in Arizona. Critical water shortages in Arizona have led to intensive investigations of methods for increasing streamflow from the State's watersheds. Results from pilot tests in chaparral, juniper, ponderosa pine, and mixed conifer vegetation types, show that streamflow responses following watershed treatments vary from zero to as much as 9 inches per year, depending on nature of the treatment, type of vegetation, and climate. - RM

2. Progress in developing multiple-use forest watershed production models. Models for evaluation of watershed management practices are being

developed based on biological, engineering and economic studies on the Beaver Creek Pilot Watersheds. Two types of models are being developed simultaneously. The first is to predict response to treatment within small watersheds and is based on comparisons of paired watersheds and analysis of hydrologic and other productivity strata within watersheds. The second type of model is for evaluation of application of a number of practices in a large river basin system. - RM

D. Stimulating Forest Management on Small Ownerships

1. Factors influencing landowners to practice forestry. Four-fifths of the commercial forest land in North Carolina is held in small tracts by farmers and other nonindustrial private owners, and a general lack of management on these holdings limits industrial development. Promotional activities by forestry agencies to encourage landowners to practice forestry could be made more effective by concentrating efforts on those categories of owners most responsive to undertaking certain kinds of practices. Owners of share-tenant farms were most inclined to plant trees and then improve woodlands. Owners of idle farms lead in planting trees; most of these were located in the Piedmont and were predominantly business and professional men. - SO

2. Southern consulting firms promote forest management. The South has 373 consultants available to serve the needs of forest owners for professional services. Virtually all of them are technically trained and highly qualified by education and experience in public or industrial service. The principal services offered are management planning, timber cruising, timber marking and sales. Many consulting firms operate crews by which their recommendations on cultural practices can be carried out. Despite the economic disadvantages of working on small tracts, most firms have provided services to ownerships of less than 20 acres. - SO

3. Timber leases and long-term cutting contracts in the South. Few of the South's wood-using industries own enough timberland to supply their raw material requirements and industry has attempted to supplement its holdings by long-term leases and cutting contracts. A survey has found that nearly 4 million acres are under leases, most of which have been made since 1955. These arrangements include provisions to manage the land to assure greater yields of timber in the future. Solution of legal, tax, and other problems associated with long-term arrangements would help expand leasing arrangements. - SO

4. Timber loans in the Federal Land Bank System. In 1944, the Columbia, South Carolina, and the New Orleans, Louisiana, banks of the Federal Land Bank System began to accept timber and forest land as sole security. A survey of Federal Land Banks has shown that forestry loans have spread throughout the United States. By late 1966 there were nearly one thousand active loans amounting to some 45 million dollars. Over 90% of the current loans are in the South. Indications are that forest credit will increase rapidly. - SO

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FOREST PRODUCTS MARKETING RESEARCH

Problems and Objectives

Timber and forest products are important sources of employment and income for several hundred thousand forest owners, wood processors, and distributors; and a basic raw material for houses, furniture, and other products used by millions of consumers. The present contribution of the forest resource can be substantially increased by more efficient use and expanded consumption of wood products. There are unused hardwood resources in the North, and softwood resources in the South, Rocky Mountains, and coastal Alaska which could support more timber-based industry, provide additional employment for local people, and increase incomes of forest owners, processors, and distributors.

The general objectives of Forest Products Marketing research are to:

1. Increase economic benefits from timber to producers and consumers by developing ways to reduce costs of harvesting, processing, distributing, and using timber products.
2. Develop more complete and efficient use of timber products, particularly residues and little-used species, and stimulate timber-based industrial development in areas where timber is available, especially in economically depressed areas such as Appalachia, the Rocky Mountains, and the northern Lake States.
3. Through appraisals of present and prospective trends in use of timber products, provide guides for marketing and investment decisions of public agencies, forest land managers, and wood product manufacturers.

Progress

A. Reducing Costs of Harvesting, Processing, Distributing and Using Timber Products

A survey of sales arrangements for thinnings and other intermediate cuts in the Pacific Northwest showed that there is a market for small saw log size thinnings down to 5 and one-half inch top diameter. Stumpage prices are lower than for old growth, but high enough to provide a profitable market for this material. More manpower and special sales arrangements are required to implement any large-scale intermediate cut program. - PNW

Analysis of National Forest stumpage prices since 1950 shows that general economic activity--not variations in sale volume--is the primary cause of price fluctuations. Variations in price are closely related to fluctuations in housing starts, gross national product, unemployment rate, and index of common stock prices. Rapid expansion of log exports tended to increase stumpage prices, but there was no clear cut price response to variations in National Forest sales volume. - PNW

Cost data from several Montana sawmills show a considerable saving in handling packaged lumber--both for producers and their customers. Use of mechanical packaging equipment is economically feasible for most mills, but packaging is not practical for all types of lumber shipments. - INT

Most lumber produced in northern Minnesota is marketed in Minnesota. Market area increases with mill size. Aspen is the leading species produced. About 45 percent of production is graded. Concentration and grading would improve marketing. Less than one-third of production residues is marketed. - NC

Jump-butting of defective sugar maple butt logs is economically justified only when the collar of sound wood is less than 6 inches thick. Otherwise, all internally defective sugar maple butts should be harvested and sawed. At a delivered cost of $70 per thousand board feet, less than one-fifth of all defective logs was unprofitable. Harvesting and sawing defective maple butts will improve use of limited, high-grade timber resources; increase sawmill operators' profit from purchased stumpage; and increase efficiency of logging by eliminating wasteful jump-butts. - NE

A study of roundwood transport practices in Appalachia clearly shows that substantial improvements can be made. Labor is scarce, yet a large percentage of log trucks is still loaded and unloaded by hand. Hauling costs could be reduced if more operators used bigger trucks. Improved woods roads would reduce expensive delays and increase profit. - NE

B. Developing Complete and Efficient Use of Timber and Wood Products

The market outlook for wood-base house sidings depends partly on improving maintenance and other performance properties, and partly on continued esthetic appeal of wood to home buyers. A survey of builders in 20 cities showed regional variation in preferences for siding. Wood-based materials are favored for appearance and workability, but are more difficult to maintain than several competing nonwood materials. - INT

Current trends in home design, improvements in window materials, and relative price of wood and aluminum windows are key factors in the market outlook for wood windows. Appearance, house style, price, and performance influence choice and contribute to wide geographic variation in window materials used in new homes. - INT

Lumber is used predominantly for shelving in new homes throughout the Nation, but builders have much interest in other materials to eliminate warp and reduce installation and finishing costs. - INT

Most new home buyers and many architects and builders do not know the facts about termites. Many people surveyed in Florida were not aware of the availability of chemical treatments for control of termites in homes with either concrete or wood floor systems. Until the facts about termite control are better understood by homebuyers, architects, and builders, many fallacies will persist and wood products will not be accepted for residential floor construction in Florida and elsewhere where termites abound. - SE

A survey of local governments of 33 cities and surrounding counties in Georgia revealed that all sample cities but only half the counties had regulatory codes. Variation in interpretation of codes was high, resulting in diverse requirements for specific applications even for communities using the same code. Local custom and preferences frequently dictate wood use requirements, and often restrict or prohibit it. Combustibility is the principal reason for restrictions on wood use by code enforcement officers. - SE

Low-grade hardwood logs can be converted into plywood by the same equipment and processes used in southern pine plywood mills. The veneer drying cycle must be lengthened slightly, but this does not affect production rate significantly. This and other information from a recent production study will be used in further study of the feasibility of producing structural plywood from Grade 3 and Tie and Timber class hardwood logs. - NE

Time studies of handling of food products when shipped piece-by-piece (floor loaded), unitized on pallets or on slip sheets, or handled by clamp trucks, showed pallets to be most efficient. Potential savings to the food industry from palletized handling amount to $3 billion annually, compared to floor loading. Complete palletization of the industry through establishment of pallet exchange systems could lead to a 400 percent increase in the demand for pallets. - NE

Due to its much longer wear life and low maintenance requirements, both the total use cost and the maintenance cost of hardwood flooring are less than for either resilient tile or carpet. Most homeowners are not informed--or are misinformed--about these costs. - NE

C. Stimulating Timber-Based Industrial Development

With continued population and economic growth in Hawaii and in mainland markets, demand for wood products will provide opportunities for industry development and expansion in Hawaii. Improved timber management can greatly increase the economic contribution of Hawaii's forests in future years. - PSW

A series of studies has shown that Black Hills ponderosa pine trees can produce veneer of sufficient volume and quality for at least C-D grade construction plywood. Nearly 77 percent of the volume in sawtimber and pole timber stands of the Black Hills National Forest and Custer State Park meet "veneerable" standards as defined by the veneer recovery study. Estimates of profitability of a mill in the Black Hills indicate that a modest profit could be realized from annual production of only 24 million square feet (3/8 inch). Profit potential rises sharply as this minimum production figure is exceeded. - RM

Wood craftsmen in Kentucky improved their skills, increased their production, and received higher returns by organizing a handicraft cooperative. Problems which persist are underutilization of producers' fixed assets, producers' lack of business knowledge, and inadequate technical training facilities. Recommendations for improvement of the cooperative have been made based on economic and cultural considerations. - NC

A case study of the decision-making process in selecting a community for the location of a multi-million dollar hardwood veneer mill showed four major factors dominated the decision: (1) location and characteristics of major market for veneer, (2) transportation facilities and costs for obtaining raw materials and shipping veneer to market, (3) availability and cost of financial assistance, and (4) management preferences with regard to physical, social, and economic environment of competing communities. Results provide a guide for communities or organizations interested in attracting industry and increasing rural employment. - NE

D. Appraising Current and Prospective Trends in Use of Timber Products

Projection of geographic distribution of softwood plywood production capacity for 1975 based on timber supplies, transportation costs, and regional costs of production suggests strong economic pressure to develop new production in the South, and in Arizona, New Mexico, and California. - PNW

Annual production of wood products from Hawaii-grown timber has ranged between 0.5 and 6 million board feet since the mid-1950's. Apparent consumption of wood in Hawaii in 1967 was 121 million board feet of lumber and 25.5 million square feet (3/8 inch) of plywood. Demand is, therefore, many times the estimated 18 to 20 million board feet potential sustained yield of Hawaii's forests. - PSW

In recent years, construction of second homes has added to the demand for residential units. A study, in cooperation with the Bureau of the Census, showed that 1.7 million of the 59 million households in the U.S. had second homes. Also, 300,000 households expected to buy or build second homes within two years. This added demand for housing will increase competition for timber and intensify the upward pressure on stumpage and product prices. - NC

Domestic timber production in 1968 is estimated at 11.8 billion cubic feet--5 percent greater than in 1967. Stumpage prices were significantly higher for softwoods, but lower for hardwoods. Softwood lumber and plywood production were up 5 and 10 percent, respectively, and prices increased sharply. Pulpwood production and prices increased slightly, while hardwood plywood production increased 5 percent without significant price change. Production of other panel products increased rapidly but prices remained stable. - WO

Preliminary reports, based on returns from 79 percent of all treating plants, indicate 256 million cubic feet of wood products were treated in 1968. Volume of plywood treated in 1968 will exceed 1967 volume by a significant margin, but volumes of all other products will apparently be lower than the volumes treated in 1967. - WO

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